LaTeX tutorial

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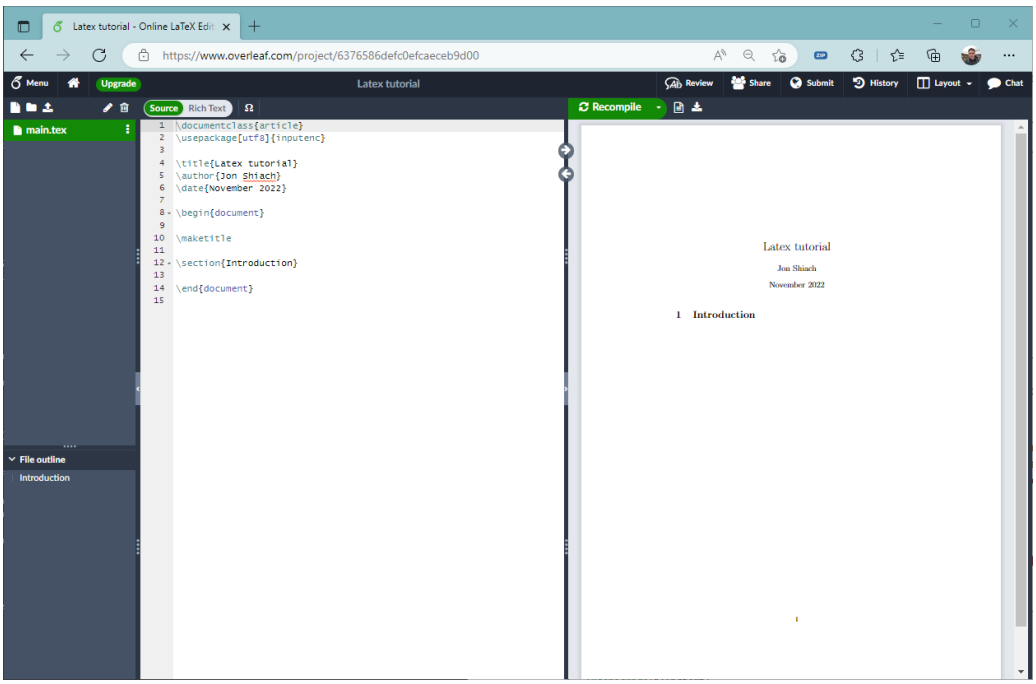
In this lab session we will be introducing you to the basics of LaTeX and how we can use it to typeset mathematics, inserting figures, hyperlinks, tables and code, create citations and reference lists and generate a table of contents. Go through the following instructions step by step and make sure the output is correct before moving onto the next one.

1. Whilst you can download and install LaTeX onto a computer we are going to use Overleaf which is a web based LaTeX editor which can be accessed from any device through a web browser and can also allow multiple authors to edit the same document. Go to www.overleaf.com and sign up for an account if you haven't already got one. It is probably best to use your personal email account to register.

2. Once you have signed into Overleaf, create a new blank project by clicking on **New Project** and call it '**LaTeX tutorial**'. This should create a file called **main.tex** which should contain the following source code.

```
\documentclass{article}
\usepackage[utf8]{inputenc}

\title{LaTeX tutorial}
\author{Your Name}
\date{October 2023}

\begin{document}

\maketitle

\section{Introduction}

\end{document}
```

   The Overleaf page will display the **source file** in the left pane and an **output file** in the right pane. LaTeX is an example of a *markup language* where text and commands are entered into the source file which is then **compiled** by LaTeX to produce the output file.



Looking at the source file the first thing you will notice is that there are a lot of backslashes `\`. These are used by LaTeX to signify when a LaTeX command is entered. A LaTeX source file consists of a **preamble** part above the `\begin{document}` command which contains commands that affect the look of the overall document. The content that you want to include in your document appear between the `\begin{document}` and `\end{document}`.

3. We want to create a document that uses A4 paper and a font size of 11pt. To do this replace `\documentclass{article}` with `\documentclass[a4paper,11pt]{article}`. Overleaf should compile the output automatically but you can make it compile by clicking on **Recompile** in the top left of the outpute pane or by saving the document by pressing **ctrl** + **s**.

4. The next change we are going to make is to add some **packages** to the source file. These extend the range of commands that we can use. To add a package we use the `\usepackage{...}` command. Copy and paste the following into your preamble above `\title{LaTeX tutorial}`.

```
% Packages
\usepackage[margin=2cm]{geometry}
\usepackage{parskip}
\usepackage{amsmath}
\usepackage{amssymb}
\usepackage[colorlinks=true,urlcolor=blue,linkcolor=blue,citecolor=blue]{hyperref}
```

Any text on the line following the percent `%` symbol is a comment and ignored by LaTeX. The `geometry` package is used here to set all margins to 2cm, the `parskip` package separates paragraphs with a blank line, `amsmath`, `amssymb` packages extend the mathematical operators and symbols available to us and the `hyperref` package makes it easy to include links in the document.

5. The `\maketitle` command puts a title at the top of the document using the information that is contained in the preamble. Change the title and date to match the following.

```
\title{\LaTeX\ tutorial}
\author{<Your first and last name>}
\date{\today}
```

The `\LaTeX\` command inserts the LaTeX logo and `\today` command inserts the current date.

6. Next we are going to enter some text into our document. Edit the source file to include the following beneath `\section{Introduction}`.

```
Words are separated by one or more spaces, however  adding   more    spaces     between
words   does  not add more spaces in the output.

Paragraphs are separated by blank lines.



Multiple blank lines do not increase the distance between paragraphs.
```

   Note that the output is collapsed. LaTeX controls the blank spaces between words and paragraphs to make the best use of the space on the page and to appear more aesthetically pleasing.

7. We can apply formatting to text, add the following to your source file.

```
Text can be formatted to appear in \textbf{bold face}, \textit{italicised},
\underline{underlined} and \emph{emphasised}.
```

8. Some symbols have special meaning in LaTeX. These include %, #, & and $. If you want to include these in your document you have to prepend it with a backslash, e.g., `\%` for the % symbol. Also, speech marks such as ‘ ’ and “ ” are entered using a backtick ` on the left and an apostrophe ' on the right. Double quotes are entered using `` and ''.

   Enter the following into your document

```
In March 2022, Congress raised borrowing to an additional \$0.79 trillion to \$8.97
trillion, which is approximately 68\% of GDP. As of October 4th 2022, the ``Emergency
Economic Stabilization Act of 2022'' raised the debt ceiling to \$11.3 trillion.
```

   which should be typeset as

> In March 2022, Congress raised borrowing to an additional $0.79 trillion to $8.97 trillion, which is approximately 68% of GDP. As of October 4th 2022, the “Emergency Economic Stabilization Act of 2022” raised the debt ceiling to $11.3 trillion.

9. Bulleted lists can be added using the `itemize` environment. Edit your source file to include the following.

```
The topics that you will study in the semester include:

\begin{itemize}
    \item Linear algebra
    \item Programming
    \item Discrete mathematics
\end{itemize}
```

   The `\item` command creates a new list item.

10. Numbered lists can be added using the `enumerate` environment. Edit your source file to include the following.

```
The steps used to calculate the greatest common divisor are:

\begin{enumerate}
    \item Divide the larger number by the smaller number and find the remainder.
    \item If the remainder is zero then the smaller number is the greatest common divisor.
    \item Replace the larger number with the smaller number and the smaller number with
    the remainder.
    \item Go to step 1.
\end{enumerate}
```

Enumerated and bulleted lists can be nested to include lists within lists. For enumerated list the item labels for the nested list are letters, (a), (b), etc. for the first level and Roman numerals, i, ii, etc. for the second level.

Typesetting mathematics

The reason that LaTeX exists is that its creator Donald Knuth was unsatisfied with the typesetting of mathematics of his books that he decided to write TeX upon which LaTeX is based. LaTeX can be used to typeset beautiful mathematics and is the go to document preparation system for mathematicians.

1. The first type of equation we are going to enter is an **inline equation** which appears alongside text in a sentence. Edit your source file to include the following.

```
\section{Typesetting mathematics}

\subsection{Inline equations}

Pythagoras' theorem is $a^{2} + b^{2} = c^{2}$ where $a$ and $b$ are the lengths of the
two shortest sides of a right-angled triangle and $c$ is the length of the hypotenuse.
```

The first thing you should notice is that the `\section` and `\subsection` commands adds section and subsection headers and automatically includes the section numbers. If you don't want section numbers we can suppress these by using `\section*{heading}` and `\subsection*{heading}` instead.

Inline equations can be typeset by writing the equation between `$...$` symbols. This tells LaTeX to use *math mode* for anything written between the delimiters so that the font is italicised and we are able to include a number of different symbols and operators[1]. The caret symbol `^` is used to write superscripts.

2. Equations that appear on a separate line and centred on the page are called **display equations**. Add the following subsection to your source file.

```
\subsection{Display equations}

Fermat's last theorem is
$$a^{n} + b^{n} \neq c^{n},$$
where $a, b, c, n \in \mathbb{N}$ and $n > 2$.
```

Display equations are typeset by writing the equation between `$$...$$` symbols[2]. Note that `\neq` inserts the $\neq$ symbol and `\mathbb{N}` is used to insert the symbol $\mathbb{N}$ (this is known as the *blackboard font*).

3. When we want to cross-reference to an equation we insert an equation number that is aligned to the right-hand margin. Edit your source file to include the following text.

[1] Inline equations can also be written using the delimiters `\(...\)`. The use of whether to use `$...$` or `\(...\)` is purely down to personal preference. This is a footnote by the way which can be entered using `\footnote {...}`.

[2] Display equation can also be written using the delimiters `\[...\]`.

```
The dot product between two vectors $\mathbf{a}$ and $\mathbf{b}$ is calculated using the
expression in eq.~\eqref{eq:dot product}
\begin{align}
    \label{eq:dot product}
    \mathbf{a} \cdot \mathbf{b} = \sum_{i=1}^n a_ib_i.
\end{align}
```

Here we have used the `align` environment to create a numbered display equation which has been assigned a label using the `\label{eq:dot product}` so we can cross-reference to this equation. The `\mathbf{a}` command typesets $\mathbf{a}$ using a bold face font, `\cdot` inserts the dot product symbol $\cdot$ and `\sum_{i=1}^{n}` inserts the summation symbol $\sum_{i=1}^{n}$[3].

The command `\eqref{eq:label}` is used to cross-reference to an equation which has been given the label `eq:label`. This inserts the equation number between parenthesis. The beauty of LaTeX is that if the equation number changes (by inserting other numbered equations above) the cross-references will update to the new equation number. The tilde ~ between `eq.` and `\eqref` inserts a non-breakable space.

4. We can use the `align*` environment to align multiple equations so that their equals signs line up. Edit your source file to include the following.

```
A system of linear equations is of the form
\begin{align*}
    a_{11} x_1 + a_{12} x_2 + \cdots + a_{13} x_n &= b_1, \\
    a_{21} x_1 + a_{22} x_2 + \cdots + a_{23} x_n &= b_2, \\
    & \vdots \\
    a_{m1} x_1 + a_{m2} x_2 + \cdots + a_{mn} x_n &= b_n.
\end{align*}
```

`\cdots` inserts the symbol $\cdots$ and `\vdots` inserts the symbol $\vdots$

By using the `align*` environment we have suppressed the equation numbering (try removing the `*`'s to see what happens). The `&` symbol is used to align each equation to the $=$ symbol.

5. Edit your source file to include the following.

```
\begin{align*}
    A =
    \begin{pmatrix}
        1 & 2 & 3 \\
        4 & 5 & 6 \\
        7 & 8 & 9
    \end{pmatrix}.
\end{align*}
```

The `pmatrix` environment is used to typeset a matrix. The columns of the matrix are separated by the `&` symbol and rows of the matrix are separated by double backslashes `\\`. The parenthesis automatically stretch to contain all of the rows of the matrix. Other types of delimiters are available, using `bmatrix` uses square brackets [ ], `vmatrix` uses vertical lines | | (e.g., for determinants), `Bmatrix` uses curly braces { } and `matrix` which does not use delimiters.

[3] There are too many symbols available to list them here but a quick internet search reveals lists such as this one. It is very common for a LaTeX user to Google "how do I do <something> in latex".

Punctuating equations

Equations form part of a sentence just like any word and should be punctuated as such. Display equations should be following by a comma if the sentence continues afterwards or a full-stop if it is the end of a sentence.

Figures and tables

1. To insert figures and tables into a document we first need to add a few packages. Edit your preamble to include the following commands.

```
% Figures and tables
\usepackage{graphicx}
\usepackage{booktabs}
\usepackage{caption}
\usepackage{float}
```

   The `graphicx` package allows us to insert images from image files into a document, `booktabs` provides better spacing in tables, `caption` provides better caption spacing and `float` provides a way of controlling the placement of the figures and tables.

2. A figure is an image such as a graph, diagram, photograph, drawing etc. that is inserted into a document. To include an image file in your document we need to upload it to overleaf. Download the image file of John Dalton by Thomas Phillips to your computer by right-clicking on the image and selecting **Save Image As...** and giving it the file name `John_Dalton.jpeg`. Then upload it to Overleaf by clicking on the upload icon in the top-left hand corner of the page.

3. Figures are entered into a document using the `figure` environment. Edit your source file to include the following.

```
\section{Figures and tables}

A portrait of John Dalton is shown in fig.~\ref{fig:john_dalton}

\begin{figure}[ht]
    \centering
    \includegraphics[width=0.5\textwidth]{John_Dalton.jpeg}
    \caption{John Dalton by Thomas Phillips}
    \label{fig:john_dalton}
\end{figure}
```

   The `\centering` command aligns the figure to the centre of the page, `\includegraphics[width=0.5\textwidth]{filename}` inserts the image file into the document and resizes it so that it takes up 50% of the width allocated for text, `\caption{...}` inserts a numbered caption[4] and `\label{...}` gives the figure a label for cross-referencing.

   A figures and tables in LaTeX are examples of a **float** which is an object which *floats* around the document and LaTeX will decide upon the best position to put it based on the amount of empty space. The use of the `[ht]` after the begin environment command tells LaTeX to put the figure as close to where it appears in the source file as possible (`h` stands for 'here') or at the top of the page if it won't fit here (`t` stands for 'top'). We can also place the figure at the bottom of the page using `[b]` or on a page of only floats using `[p]`.

   Sometimes we want to override the float and place it exactly where it appears in the text, in these cases we can use the `float` package and use the location specifier `[H]`. Edit your source file so that the figure is always where it appears in the text.

[4] Figure captions should always appear below the figure. It should be clear to the reader what the figure is showing before reading the caption.

4. Tables are entered into a document using the `table` and `tabular` environments. Edit your source file to include the following.

```
Some of the symbols used in set theory are shown in table~\ref{tab:set_theory_symbols}.

\begin{table}[ht]
    \centering
    \caption{Set theory symbols.}
    \label{tab:set_theory_symbols}
    \begin{tabular}{cl}
        \toprule
        Symbol & Meaning \\
        \midrule
        $\in$ & is a member of \\
        $\cup$ & union \\
        $\cap$ & intersection \\
        $\subset$ & subset \\
        $\supset$ & superset \\
        $\emptyset$ & empty or null set \\
        \bottomrule
    \end{tabular}
\end{table}
```

The `centering`, `\caption`[5] and `\label` commands do the same as in the `figure` environment. The `tabular` environment is used to define the table with the number of columns and their horizontal alignment specified in curly braces. Here we have `{cl}` which specifies two columns, the first being centrally aligned and the second is left aligned (for right aligned we use `r`). An ampersand `&` separates the columns of the table and double backslashes `\\` separate the rows similar to matrices seen above. The `\toprule`, `\midrule` and `\bottomrule` commands create the horizontal borders[6].

[5] Table captions should always appear above the table. The reader needs to know what the data in the table is showing to understand it.

[6] Use of vertical borders in tables is generally discouraged and should only be used where absolutely necessary.

Referencing and cross referencing

We have already seen examples of cross referencing where the `\ref{fig:label}` command returns the number of the document element that has been assigned the label `fig:label` and `\eqref{eq:label}` which returns the equation number of the equation with the label `eq:label`. We can also return the page number of a document element using `\pageref{fig:label}` which is useful if the document has a large number of pages.

The referencing of sources is done in LaTeX using BibTeX and the `biblatex` package. The preferred method of referencing at the Manchester Metropolitan University is the Harvard method and a comprehensive referencing guide and be found at Cite Them Right.

1. To configure the `biblatex` package to use the Harvard method copy and paste the following into your preamble.

```
% Referencing (set up for cite them right Harvard referencing)
\usepackage[backend=biber,
            citestyle=authoryear,
            bibstyle=authoryear,
            maxcitenames=3,
            urldate=long,
            natbib]{biblatex}
\addbibresource{references.bib}
\DeclareNameAlias{author}{family-given}
\DeclareFieldFormat[article,periodical]{volume}{#1}
\DeclareFieldFormat[article,periodical]{number}{(#1)}
\DeclareFieldFormat[article,periodical]{title}{`#1'}
\DefineBibliographyStrings{english}{urlseen = {Accessed:},url = {[Online]. Available at}}
\DeclareFieldFormat[online]{url}{Available at: \url{#1}}
\setlength\bibitemsep{0.5\baselineskip}
```

2. The information for your sources are contained in a separate BibTeX file. To create this file click on the new file icon in the top-left corner of the Overleaf page and give it the filename `references.bib`.

3. Click on '**references.bib**' in the file menu on the left hand side of the page and enter the following.

```
@book{strang:1993,
    title={Introduction to {L}inear {A}lgebra},
    author={Strang, Gilbert},
    volume={3},
    year={1993},
    publisher={Wellesley-Cambridge Press Wellesley, MA}
}
```

   This has created a BibTeX entry that includes the citation information for the book *Introduction to Linear Algebra* by Gilbert Strang. Curly brackets are used in the title field to ensure that '*Linear Algebra*' is in title case (BibTeX defaults to sentence case for titles).

4. To cite the source we have just entered we can use the `\citet{}` command. Edit your source file to include the following.

```
The book \emph{``Introduction to Linear Algebra''} was written by \citet{strang:1993}.
```

   The `\citet{strang:1993}` command has cited the BibTeX entry with the label `strang:1993` and entered the citation 'Strang (1993)' in the document, this is used when the author's name is part of the text (hence the `t` in `citet`). The `\emph{}` command applies emphasis to the text which has the effect of italicising it.

5. To cite a source when the author's name is not a part of the sentence (which is far more common)

we use the `\citep{}` command. Edit your source file to include the following.

```
If square matrix $A$ has an inverse, then both $A^{-1} A = I$ and $A A^{-1} = I$
\citep{strang:1993}.
```

The `\citep{strang:1993}` has cited the same source as before but this time the author's name and year or publication are contained within parenthesis (hence the `p` in `citep`).

6. We can also cite a particular page within a source. Edit your source file to include the following.

```
An eigenvector $\mathbf{x}$ lies along the same line as $A \mathbf{x}$ :
$A \mathbf{x} = \lambda \mathbf{x}$. The eigenvalue is $\lambda$
\citep[p. 288]{strang:1993}.
```

Inserting `[page 288]` after `\citep` command appends ', page 288' to the year.

7. The BibTeX item we added was for a citation of a book. There are a variety of different types of sources which are cited in slightly different ways (see Cite Them Right). For example, to cite a webpage we need the URL of the page as well as the date accessed (as unlike books, web pages can and do change). Edit your source file to include the following.

```
@online{shiach:2023,
    title={Linear Algebra Lecture Notes},
    author={Shiach, J},
    url={https://jonshiach.github.io/LA-book},
    year={2023},
    urldate={2023-10-25}
}
```

This adds a BibTeX item with the citation information for the Linear Algebra Lecture notes. The `year` field is the year that the web page was last updated and the `urldate` field is the date which we have accessed the page using the format `yyyy-mm-dd`.

8. Edit your source file to include the following.

```
A system of linear equations is a collection of one or more linear equations expressed
using the same set of variables. \citep{shiach:2023}
```

9. So far we have added citations to two sources but have not included a reference list. To add this to our document we use the `\printbibliography` command. Edit your source file to include the following.

```
\printbibliography
```

This adds a new section which contains the reference list. The list is ordered in alphabetical order by the author's surnames. The reference list should appear at the end of the document (but before the appendices if there are any).

Code listings

1. When including code listings in a document it is helpful to the reader to format the code so that it resembles the formatting used when writing the code. To do this in LaTeX we can add the `lstlistings` package and configure some options. Copy and paste the following into your preamble.

```
% Code listings (for including computer code into your document)
\usepackage{listings}
\usepackage{lstautogobble}
\definecolor{codegreen}{rgb}{0,0.6,0}
\definecolor{codegray}{rgb}{0.5,0.5,0.5}
\definecolor{codepurple}{rgb}{0.58,0,0.82}
\definecolor{backcolour}{rgb}{0.95,0.95,0.95}

\lstset{
    backgroundcolor=\color{backcolour},
    commentstyle=\color{codegreen},
    keywordstyle=\color{blue},
    numberstyle=\tiny\color{codegray},
    stringstyle=\color{codepurple},
    basicstyle=\ttfamily\footnotesize,
    breaklines=true,
    captionpos=t,
    frame=single,
    rulecolor=\color{lightgray},
    autogobble = true,
}
```

2. When can use the `lstlisting` environments to enter code into our document. Copy and paste the following into your document.

```
\section{Code listings}

Python code for defining a function to check whether a number is prime is shown in
listing~\ref{py:isprime}.

\begin{lstlisting}[
        language = python,
        caption = A Python function for determining whether a number is prime.,
        label = py:isprime
    ]
    def isprime(x):
        for i in range(2, x):
            if x % i == 0:
                return False
        return True
\end{lstlisting}
```

   The `lstlisting` environment creates a float similar to figures and tables and we can add a caption and label in a similar way (these are optional). The code is automatically formatted using syntax highlighting for the language specified in the square brackets. The code can then be copied and pasted from an editor.

   For code appearing inline we can use the `\lstinline{code}` command.

Table of contents and lists of figures, tables and code listings

For larger documents (say more than 10 pages), it is useful to include a table of contents and lists of figures, tables and code listings.

1. To insert a table of contents we simply use the command `\tableofcontents`. Edit your source file so that it looks like the following.

   ```
   \begin{document}

   \maketitle
   \tableofcontents

   \section{Introduction}
   ```

   This adds a table of contents after the title which contains the headings of the sections and subsections in the document. This will automatically update as we add more content to the document.

2. We can also add lists of the figures, tables and code listings to our document. Edit your source file to include the following.

   ```
   \listoffigures
   \listoftables
   \listoflistings
   ```

   Since our document is quite small this is probably unnecessary, but it can be useful when we large documents with lots of pages.

Appendices

We can specify the beginning of the appendices using the `\appendix` command. Appendices are useful for including content that would upset the flow of the main document, e.g., data tables, code listings etc.

Edit your code to include the following.

```
\newpage
\appendix
\section{Appendices}

\begin{lstlisting}[
    caption = A preamble for a \LaTeX\ document,
    label = tex:preamble
    ]
    <copy and paste your preamble here>
\end{lstlisting}
```

The `\newpage` command acts as a page break and the `\appendix` command changes the section numbering of all subsequent sections to use uppercase letters instead.

By now your preamble section contains a number of commands and settings. Rather than trying to remember these each time you create a LaTeX document, we can just copy and paste from this one. Over time your preamble section may grow as you use more packages and even create your own commands

Other useful stuff

Hyperlinks

You can include hyperlinks in your document using the `hyperref` package. To insert a link to a webpage use the following

```
\href{<webpage url>}{<text>}
```

For example

```
Details of the course can be found on the \href{https://www.mmu.ac.uk}{university website} or by
emailing me at \href{mailto:j.bloggs@mmu.ac.uk}{j.bloggs@mmu.ac.uk}.
```

would be typeset as

> Details of the course can be found on the university website or by emailing me at j.bloggs@mmu.ac.uk.

Defining your own commands

As you get used to writing documents you may find yourself using the same text or commands over and over again. This is where it is useful to define your own commands using the following

```
\newcommand{\commandname}{<command>}
```

For example, the command below creates a new command called `\mmu` which inserts the name of the university.

```
\newcommand{\mmu}{Manchester Metropolitan University}
```

This can then be used like so

```
I study at the \mmu.
```

which would be typeset as

> I study at the Manchester Metropolitan University.

Commands can also take in a number of inputs similar to a function in programming. To do this we use the following.

```
\newcommand{\commandname}[number of inputs]{...#1...#2...}
```

The inputs are then entered using #1, #2 etc. For example, lets say we regularly write derivatives using the following.

```
\frac{\mathrm{d} y}{\mathrm{d} x}
```

which typesets as $\frac{\mathrm{d}y}{\mathrm{d}x}$ (the `\mathrm{d}` command typesets a non-italicised d which is how derivatives should be written). We could define a command called `\deriv` which takes in two inputs and inserts the derivative.

```
\newcommand{\deriv}[2]{\frac{\mathrm{d}#1}{\mathrm{d}#2}}
```

This can then be used in an equation.

```
\deriv{s}{t}
```

which typesets as $\frac{\mathrm{d}s}{\mathrm{d}t}$.

For more information on defining your own commands see the Overleaf help pages.