Introduction to LaTeX for Scientific Reports and Dissertations

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1 Introduction

In most cases, there are two programming options for writing scientific papers or dissertations. The first is to use MS Word. This WYSIWYG ("what you see is what you get") program is very convenient, especially for documents such as letters, memos, and short simple papers. With Word, the author is responsible for both the visual design and the content of the document. The second option is to use the high-quality document typesetting program known as LaTeX, which is arguably the de facto standard for scientific publishing. The philosophy of LaTeX is to separate the formatting of a document from the content so the author can concentrate on the writing, while still allowing manual typesetting adjustments when needed. Journals frequently use LaTeX to produce final versions of papers, or use it as a pipeline to XML and other formats. LaTeX has numerous advantages when writing complex scientific papers and dissertations, some of which will be described in this document. LaTeX is freely available for all popular computer operating systems.

Producing a LaTeX manuscript is a two-step process: (1) Using a plain text editor, the author creates a document incorporating all the desired text formatting tags. (2) The LaTeX program is then used to interpret the plain text document, converting it into a formatted PDF file. By convention, the plain text file must have the extension .tex.

2 Structure of a LaTeX document

2.1 Commands

LaTeX files (*.tex) consist of the manuscript's text and the processing commands needed to format the document. Commands typically have the form

commandname[*optional_argument*]{*mandatory_argument*}

If no optional or mandatory arguments are required, the associated brackets can be omitted. Examples of commands include:

```
\newpage
\vspace{2ex}
\documentclass{article}
\documentclass[11pt]{thesis}
\rule[-2mm]{1mm}{16cm}
```

2.2 Environments

Environments are portions of a document that are treated differently from that of the surrounding material. For example the indentation, typeface, line width, and other features may be different. Environments are delineated by the \begin{*environment*} and \end{*environment*} commands. For example:

```
\begin{itemize}
  list of items
\end{itemize}
```

and

```
\begin{figure}
  figure graphic and caption
\end{figure}
```

2.3 Declarations

A declaration is a command that changes the value or meaning of certain parameters. For example, \Large will change the font size relative to the base font to Large. Declarations remain in effect until they are superceded by a new declaration affecting the same parameter (such as font size).

2.4 Preamble

Every LaTeX document must include a *preamble* and a *body*. The preamble is used to specify global items that persist throughout the document such as document style, paper size, margin widths, default font size, names of any external packages used to enhance basic LaTeX, and any additional commands the author chooses to define.

The only required command in the preamble is the \documentclass[*options*]{*class*} command which sets the overall style or *class* of a document; LaTeX will use defaults for everything else if no further commands are given in the preamble. Standard LaTeX styles (classes) include: article, report, book, slides, letter, and beamer. Each class consists of a set of rules that define the look and structure of the style. Thus, to select the article style for a document, type:

```
\documentclass[options]{article}
```

which tells LaTeX to look for the style rules in the file article.cls which comes bundled with a standard LaTeX package. *Options* include things like the base font size, the paper size, whether the document should be in one-column or two-column format, whether the document should be in one-sided or two-sided format, and whether equations should be centered or set flush left. For example, to produce a two-column, two-sided article with 11pt font and flush left equations, use:

```
\documentclass[11pt,twoside,twocolumn,fleqn]{article}
```

Articles and reports consist of sections, subsections, and subsubsections while books consist of chapters, sections, and subsections.

Since LaTeX is intended to be extendable, many organizations have developed their own style (*.cls) files to suit their particular needs. This includes most scientific journals. These journal or publisher *.cls files are typically based on the article class and are freely provided to authors through the journal's website. As an example, to submit a paper to Earth Surface Dynamics (a Copernicus publication), download the file copernicus.cls from ESD's website. Then include the line,

```
\documentclass[esd,manuscript]{copernicus}
```

as the first line of your preamble. The document will then be automatically created using ESD's style rules.

Theses and dissertations at most universities are based on the book class which has been modified to accommodate the university's particular style requirements. The style for University of Colorado theses and dissertations is provided by the thesis.cls file available at https:

//oit.colorado.edu/software-hardware/tex-latex/thesis-class. For CU dissertations, the first line of the preamble is then

```
\documentclass[defaultstyle,11pt]{thesis}
```

2.5 Body

The body, delineated by \begin{document} and \end{document} commands, consists of the manuscript's text mixed with various commands. Unlike the preamble, commands within the body have only a local effect. Also within the body, LaTeX is either in *text* mode or *math* mode. These modes will be described further in Sections 3 and 4. In summary, the general structure of a LaTeX file is,

```
\documentclass[options]{class}          % begin preamble
  additional global commands and specifications
\begin{document}                        % begin body
  document text mixed with additional local commands
\end{document}                          % end body
  any text that you don't want typeset (this is a good place for notes)
```

3 Text Mode

By default, LaTeX is in text mode. This is the mode in which the author inserts the bulk of their manuscript.

3.1 Font size

The base font size for a document can be specified by an option in the \documentclass command*. For example, \documentclass[11pt]{article}. Allowable sizes are 10, 11, and 12 pt. LaTeX will automatically scale the base font size when making section headings, footnotes, or in any other situation where the font size in a document normally changes.

The font size relative to the base font can be modified at any point in a document by issuing one of the font declarations: \tiny, \scriptsize, \footnotesize, \small, \normalsize \large, \Large, \LARGE, \huge, \Huge. For example,

This is normal text. Now we're switching to \tiny text, up to \LARGE text, and back to \normalsize text.

3.2 Font attributes

Standard LaTeX includes three font families, four font shapes, and two font series. These are activated by the following declarations:

*The base font size is typically not an option when utilizing a journal's *.cls file since the journal will explicitly set the font size.

Family:

\rmfamily to switch to the Roman font (this is the default font)
\ttfamily to switch to `typewriter` font
\sffamily to switch to san serif font

Shape:

\upshape to switch to an upright font (default)
\itshape to switch to an *italic* shape
\slshape to switch to a *slanted* shape
\scshape to switch to Caps and Small Caps

Series:

\mdseries to switch to medium weight (default)
\bfseries to switch to a **bold** font

A font declaration will remain in effect until it is superceded by a new font declaration.

For each font declaration, there is a corresponding font command. These commands are convenient when an attribute will only be applied over a limited amount of text. The corresponding commands are:

Family:	\textrm{*text*}	\texttt{*text*}	\textsf{*text*}	
Shape:	\textup{*text*}	\textit{*text*}	\textsl{*text*}	\textsc{*text*}
Series:	\textmd{*text*}	\textbf{*text*}		
Default:	\textnormal{*text*}			
Emphasis:	\emph{*text*}			

Thus, **text can be bold faced** using the \textbf{} command or *emphasized using the* \emph{} command. It's also possible to nest commands. For example, \textbf{\textsl{*text*}} can be used to make ***bold slanted text***.

3.3 Sectioning commands

The commands to begin a section in an article, report, book, or dissertation are:

\chapter	<for books and dissertations>
\section	
\subsection	
\subsubsection	

LaTeX will automatically set the font size and vertical spacing for the section headings.

3.4 Centering and indenting

Centering lines of text is accomplished using the centering environment,

```
\begin{center}
  line 1 \\
  line 2 \\
      ⋮
\end{center}
```

Note that since LaTeX ignores carriage returns and line feeds, the \\ command can be used to produce a line break.

Occasionally, the first line of a paragraph will be indented when you don't want an indentation. To prevent this, use the \noindent command. A section of text can be displayed with an equal amount of indentation on the left and right using the \begin{quote} *text* \end{quote} environment, as in:

> Penitentes are snow formations, found at high elevations, which form of elongated, thin blades of hardened snow or ice up to 5 meters in height, closely spaced and pointing towards the general direction of the sun. They are evolved suncups.

3.5 Lists

The three environments for producing formatted lists are:

\begin{itemize}	*the list*	\end{itemize}
\begin{enumerate}	*the list*	\end{enumerate}
\begin{description}	*the list*	\end{description}

These environments only differ in terms of the label or marker used for each list item. For *itemize* the item marker is a symbol, for *enumerate* it is a number, while for *description* it is a word or phrase in bold face. For example,

```
\begin{itemize}
\item Lake-effect snow
\item thundersnow
\end{itemize}
```

produces

- Lake-effect snow
- thundersnow

while

```
\begin{description}
```

```
\item[Lake-effect snow] Lake-effect or ocean-effect snow occurs when relatively cold air flows over warm lake (or ocean) water to cause localized, convective snow bands.

\item[thundersnow] Thundersnow occurs when a snowstorm generates lightning and thunder. It may occur in areas that are prone to a combination of wind and moisture triggers that promote instability, often downwind of lakes or in mountainous terrain.

\end{description}
```

produces,

Lake-effect snow Lake-effect or ocean-effect snow occurs when relatively cold air flows over warm lake (or ocean) water to cause localized, convective snow bands.

thundersnow Thundersnow occurs when a snowstorm generates lightning and thunder. It may occur in areas that are prone to a combination of wind and moisture triggers that promote instability, often downwind of lakes or in mountainous terrain.

3.6 Footnotes

Footnotes are strongly discouraged in journal articles. Nonetheless, they can be useful in other situations such as dissertations. Footnotes can be created using the command \footnote{*footnote_text*} at the location where the footnote marker first appears. LaTeX will automatically place the footnote text at the bottom of the page. For example,

```
Lake-effect snow\footnote{Lake-effect or ocean-effect snow occurs when relatively cold air flows over warm lake (or ocean) water to cause localized, convective snow bands.} frequently occurs in Salt Lake City during the winter.
```

produces

Lake-effect snow[†] frequently occurs in Salt Lake City during the winter.

The actual footnote appears at the bottom of this page. To change the style of the footnote marker, issue the

```
\renewcommand{\thefootnote}number_style{footnote}}
```

command. Available styles include: \arabic, \roman, \Roman, \alph, \Alph, and \fnsymbol. LaTeX will automatically increment the footnote counter and associated marker each time a footnote command is issued. Thus for \arabic, the markers are 1, 2, 3, 4, 5 ... while for \fnsymbol they are ∗, †, ‡, §, ¶ ....

3.7 Boxes

A LaTeX *box* is a portion of text that's treated as a unit and thus can't broken up by a page break or other text breaking event. Unlike ordinary text, a box can be moved as a unit to a different position (up, down, left, right).

[†] Lake-effect or ocean-effect snow occurs when relatively cold air flows over warm lake (or ocean) water to cause localized, convective snow bands.

3.7.1 Paragraph boxes

A paragraph box is a piece of text (a single line or an entire paragraph) that is fit into a box of a specified width. It is created using the command,

\parbox[*pos*]{*width*}{*text*}

where the optional parameter *pos* can take on the values b to align the bottom of the box with the current baseline or t to align the top of the box with the baseline. Thus,

```
\begin{center}
\parbox{5cm}{Snowsqualls are brief, but intense periods of moderate to heavy snowfall with strong, gusty surface winds and measurable snowfall.}
\end{center}
```

produces,

Snowsqualls are brief, but intense periods of moderate to heavy snowfall with strong, gusty surface winds and measurable snowfall.

A frame can be placed around the box using the \fbox{ } command. In the above example,

```
\begin{center}
\fbox{\parbox{5cm}{Snowsqualls are brief, but intense periods of moderate to heavy snowfall with strong, gusty surface winds and measurable snowfall.}}
\end{center}
```

produces,

Snowsqualls are brief, but intense periods of moderate to heavy snowfall with strong, gusty surface winds and measurable snowfall.

Additional \parbox parameters are available to control the height and other aspects of the box.

3.7.2 Rule boxes

A *rule* box is a filled-in rectangle created with the command,

\rule[*lift*]{*width*}{*height*}

where the optional parameter *lift* is the amount the box is lifted above the current baseline and *width*, *height* specify the dimensions of the box. Thus,

```
\begin{center}
\rule{12cm}{0.5mm}
\end{center}
```

produces a line that may be useful for dividing sections of material,

---

3.8 Comments within the text

Sometimes it's useful to place a comment in the text that you don't actually want to be typeset. To do this, simply use the % character. For example,

```
% This is our most important figure! Let's make it full page. —
\begin{figure}
  figure graphic and caption
\end{figure}
% Check that the reference cited in the caption is correct!
```

LaTeX will completely ignore the lines beginning with the % character.

3.9 Fine-tuning text

3.9.1 Spacing

Since LaTeX is a typesetting program, it automatically handles typography, i.e. the distance between letters and between words. As a result, LaTeX doesn't care how many blank spaces occur between words in the *.tex file. One blank space has the same effect as a hundred. A single carriage return is also ignored since LaTeX determines how many words to put on a line and when it's necessary to hyphenate, something else it does automatically. However, two carriage returns in a row signal LaTeX to begin a new paragraph.

Sometimes you might want to override LaTeX and add a bit of horizontal space. A small horizontal space can be added by inserting the \, command. More generally, horizontal space can be added using the \hspace{*space*} command where *space* is the length of space to insert, for example 8mm or 1.5em; em is the width of the letter M. To reduce space, set parameter *space* to a negative number. The corresponding command to add or reduce vertical space is \vspace{*space*}. Here, *space* could for example be 3.1cm, -1.5in, or 2ex where ex is the height of the letter X.

3.9.2 Gluing Text Together

In best practice, some pieces of text should not be separated by a line or page break. Examples include a number with an associated unit (8 mm), references to a particular figure (Fig. 3) or table (Table 2), and short abbreviations (J. Climate). To prevent these items from becoming separated, use the special character ~ instead of a space. For example, 8~mm or J.~Climate.

3.9.3 Periods

LaTeX interprets a period following a lower case letter as a signal to end a sentence. It then inserts an inter-sentence space following the period. In some cases, this interpretation produces more horizontal space than desired (e.g., Geophys. Res. Lett.). To reduce the amount of space after a period, follow the period with a backslash, e.g., Geophys.\Res.\Lett. produces Geophys. Res. Lett.

3.9.4 Dashes

Typesetters recognize three types of dashes: the *hyphen* used in compound words (e.g., state-of-the-art), the *en dash* used for a range of numbers (e.g., 325–349), and the *dash* (e.g., National Petroleum Reserve—Alaska). These are produced by typing one, two, or three keyboard dashes respectively, i.e. -- for an *en dash*. Note that the negative sign on a number is a mathematical symbol and thus not replicated by any of these text dashes. To produce the number minus 5, one should use math mode as described in Section 4 (e.g., -5 produces -5).

3.9.5 Quotation Marks

The double quote character ″ found on keyboards isn't used in high-quality typesetting. In LaTeX, single quotes are produced by the forward ‘ and backward ’ quotes found on keyboards while double quotes are made by typing these characters twice to make “ and ”.

3.9.6 Special Characters

The characters # $ ~ % { } _ are all special characters that LaTeX interprets as being part of a command. In order to print these characters, precede them with a backslash. Thus, to print 50%, use 50\%.

3.9.7 Foreign Letters and Accents

The various accents used in European languages can be produced with the commands:

ò = \‘{o}	ó = \’{o}	ô = \^{o}	ö = \”{o}	õ = \~{o}
ō = \= {o}	ȯ = \.{o}	ŏ = \u{o}	ǒ = \v{o}	ő = \H{o}
o͡o = \t{oo}	ǫ = \c{o}	ọ = \d{o}	ọ̲ = \b{o}	ů = \r{o}

and the special letters by:

œ = {\oe}	Œ = {\OE}	æ = {\ae}	å = {\aa}	Å = {\AA}
ø = {\o}	Ø = {\O}	ł = {\l}	Ł = {\L}	ß = {\ss}
¡ = !‘	¿ = ?‘			

4 Math Mode

Typesetting mathematical equations in a visually appealing way is a complex undertaking. LaTeX excels at this. Mathematical material can either occur within a line of text, such as $y = x^2 - 3$, or separated from the main text as in,

$$Q = \int_0^\infty f(x)\,dx. \tag{1}$$

In either case, LaTeX must be informed when the mathematical material begins and when it ends. For intraline math text, this can be accomplished by delineating the beginning and end of the mathematical material with $ symbols, e.g., $y = x^2 - 3$. To create mathematical material separated from the main text, use one of LaTeX's *displayed formula* environments,

\begin{displaymath}	*formula_text*	\end{displaymath}
\begin{equation}	*formula_text*	\end{equation}
\begin{eqnarray}	*formula_text*	\end{eqnarray}
\begin{eqnarray*}	*formula_text*	\end{eqnarray*}

Here, the displaymath and equation environments are designed for single-line equations while eqnarray and eqnarray* are for multi-line equations and arrays. The equation and eqnarray environments automatically generate sequential equation numbers while the other two forms do not. As an example, Eq. (1) above was produced using the equation environment,

```
\begin{equation}
Q = \int_0^\infty f(x) dx .
\end{equation}
```

4.1 Primary elements of math mode

The general practice in mathematical typesetting is to display constants in Roman typeface while variables are in italics. LaTeX handles this automatically in math mode. The following mathematical symbols available on the keyboard can be used directly in math mode: $+ - = < > / : ! ' | [ ] ( )$.

Exponents and indices. Typographically the same as superscripts and subscripts, exponents and indices are easily produced with the ^ and _ commands, respectively. Thus, x^3 produces x^3 while x_i produces x_i. In math mode, curly braces are used to logically group pieces of a formula together. For example, x^{2 i} produces x^{2i} while A_{i,j,k}^{-n!2} produces $A_{i,j,k}^{-n!2}$.

Fractions are created with the \frac{*numerator*}{*denominator*} command. For example,

```
\begin{displaymath}
\frac{\psi_2}{2\chi_2 + 1} .
\end{displaymath}
```

produces,

$$\frac{\psi_2}{2\chi_2 + 1}.$$

Intraline fractions are best displayed using $*numerator*/*denominator*$, as in $x/(x+y)$ which produces $x/(x+y)$.

Square roots can be produced using the \sqrt{*argument*} command. Thus, \sqrt{x^2 + y^2} produces $\sqrt{x^2 + y^2}$.

Sum and integral signs are created with the \sum and \int commands. Thus,

```
\begin{displaymath}
\sum_{i=1}^n x_i
\end{displaymath}
```

produces

$$\sum_{i=1}^{n} x_i$$

while

```
\begin{displaymath}
\int_a^b f(x) dx .
\end{displaymath}
```

produces

$$\int_a^b f(x)\,dx.$$

4.2 Mathematical symbols

An enormous number of mathematical symbols are available in LaTeX. Some of the more commonly used ones are:

$\pm$ \pm	$\times$ \times	$\div$ \div	$\cdot$ \cdot	$*$ \ast	$\star$ \star	$\dagger$ \dagger	$\diamond$ \diamond
$\ddagger$ \ddagger	$\circ$ \circ	$\bullet$ \bullet	$\leq$ \le	$\ll$ \ll	$\geq$ \ge	$\gg$ \gg	$\neq$ \neq
$\approx$ \approx	$\equiv$ \equiv	$\sim$ \sim	$\simeq$ \simeq	$\mid$ \mid	$\parallel$ \parallel	$\prime$ \prime	∇ \nabla
∂ \partial	∞ \infty	$\forall$ \forall	$\exists$ \exists	$\triangle$ \triangle			

$\leftarrow$ \leftarrow	$\rightarrow$ \rightarrow	$\Leftarrow$ \Leftarrow	$\Rightarrow$ \Rightarrow
$\longleftarrow$ \longleftarrow	$\longrightarrow$ \longrightarrow	$\Longleftarrow$ \Longleftarrow	$\Longrightarrow$ \Longrightarrow
$\clubsuit$ \clubsuit	$\diamondsuit$ \diamondsuit	$\heartsuit$ \heartsuit	$\spadesuit$ \spadesuit

For a more complete list of available math symbols in TeX[‡] and LaTeX, see https://en.wikipedia.org/wiki/List_of_mathematical_symbols.

4.2.1 Brackets

Brackets are used in mathematics to logically group portions of a formula together with the hierarchy being ( ) for the inner group, [ ] for the next level, and then { } for the third level. As with ordinary text, the curly brackets { } are used for commands in math mode. In order to print them, you must once again precede the curly brackets with a backslash \.

Although you can use the brackets ( ), [ ], \{ \} directly in a formula, it's best to use the forms \left(, \right), \left[, \right], \left\{, \right\} to make the brackets the same size as the material they enclose. Note that these forms must be used in pairs. A left bracket without a corresponding right bracket will produce an error when attempting to typeset the document. As an example of automatic bracket sizing, consider:

[‡] LaTeX is a macro version of TeX; all the symbols available in TeX are also available in LaTeX.

```
\begin{displaymath}
f = a \left[ \frac{x_1 + 3 \left( \frac{x_2}{2y_2 + 1} + \frac{x_3}{2y_3 + 1} \right) }{x_1 +
3 \left( \frac{x_2 y_2}{2y_2 + 1} + \frac{x_3 y_3}{2y_3 + 1} \right)} \right] .
\end{displaymath}
```

which produces

$$f = a \left[\frac{x_1 + 3 \left(\frac{x_2}{2y_2 + 1} + \frac{x_3}{2y_3 + 1} \right) }{x_1 + 3 \left(\frac{x_2 y_2}{2y_2 + 1} + \frac{x_3 y_3}{2y_3 + 1} \right)} \right] .$$

Sometimes you may want only a left bracket, or only a right bracket. To circumvent the rule that brackets be used in pairs, LaTeX allows you to substitute an invisible bracket for the one you don't want to print. To do this, use a period '.' for the invisible bracket, as in,

```
\begin{displaymath}
\psi(x) = \left\{                    % curly left bracket
  \begin{array}{rc}
  -1, & x < 0 \\
  0, & x = 0 \\
  1, & x > 0
  \end{array}
\right.                              % invisible right bracket
\end{displaymath}
```

which produces

$$\psi(x) = \left\{ \begin{array}{rc} -1, & x < 0 \\ 0, & x = 0 \\ 1, & x > 0 \end{array} \right.$$

The array environment used in this example is described in Section 6.

4.2.2 Accents

A number of mathematical accents are available in LaTeX, including:

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

4.2.3 Continuation dots

LaTeX provides several kinds of continuation dots in math mode. They are:

\ldots	$\ldots$	*low dots*	\cdots	$\cdots$	*center dots*
\vdots	$\vdots$	*vertical dots*	\ddots	$\ddots$	*diagonal dots*

Thus, a_0 + a_1 + \cdots + a_n produces $a_0 + a_1 + \cdots + a_n$ while a_0, a_1, \ldots, a_n produces $a_1, a_2, \ldots, a_n$. The \ldots command is also available in ordinary text mode.

4.3 Math fonts

Greek letters: All the upper and lower case greek letters are available in math mode, including a number of variants commonly used in physics and in Europe. For example, \alpha, \beta, \epsilon, \varepsilon, \theta, \vartheta, \Theta, \pi, \varpi, \xi, \Xi produce $\alpha, \beta, \epsilon, \varepsilon, \theta, \vartheta, \Theta, \pi, \varpi, \xi, \Xi$.

Calligraphic letters are also available in math mode using the command \mathcal{*arg*} where *arg* is any of the capital letters A, B, C, ... Z. For example, \mathcal{E, F, G} produces $\mathcal{E}, \mathcal{F}, \mathcal{G}$.

Math bold: By convention, vectors are normally displayed in bold typeface. To achieve this, use the \mathbf{*arg*} command. For example, use \mathbf{V} to produce $\mathbf{V}$.

Ordinary text: Occasionally, it's necessary to produce ordinary text inside a math environment, such as when providing units in an empirical equation. To do this, use the \mathrm{*arg*} command. For example,

```
\begin{displaymath}
k(T) = \sum_{i=1}^4 a_i \left( \frac{T}{300 \mathrm{K}} \right)^{b_i} , \hspace{3em}
250 \mathrm{K} < T \le 383 \mathrm{K}
\end{displaymath}
```

produces

$$k(T) = \sum_{i=1}^{4} a_i \left(\frac{T}{300 \mathrm{K}} \right)^{b_i}, \qquad 250 \mathrm{K} < T \le 383 \mathrm{K}$$

Chemical formulas: By convention, chemical formulas are displayed in Roman font. Thus,

$$2\mathrm{HCl} + \mathrm{NaCO_3} \longrightarrow 2\mathrm{NaCl} + \mathrm{H_2O} + \mathrm{CO_2}$$

can be written as,

```
$\mathrm{2H Cl + Na CO_3} \longrightarrow \mathrm{2Na Cl
+ H_2 O + CO_2}$.
```

4.4 Additional elements of math mode

4.4.1 Function names

The standard is to print function names in Roman font. This can be done using the \mathrm command but LaTeX already recognizes a large number of functions with the following commands:

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

Thus, rather than typing $\mathrm{sin}(2x)$, one can type $\sin(2x)$ to produce $\sin(2x)$.

4.4.2 Horizontal spacing

In math mode, LaTeX ignores any blank spaces present in the equation text. Although this works fine in most instances, LaTeX doesn't understand the mathematical meaning of an equation and thus sometimes needs a little help with the spacing. For example, in the equation $f(x) = \int xdx$, LaTeX leaves too little space between the variable x and the differential operator dx. To fine-tune the spacing, insert the following commands where needed,

- \, small space
- \: medium space
- \; large space
- \! small negative space

For example, $f(x) = \int x\: dx$ produces $f(x) = \int x\, dx$.

4.4.3 Multi-line equations

A multi-line equation shows the development of an equation over several lines in which the = or other relationship sign such as ≤ are vertically aligned. This is produced using the eqnarray or eqnarray* environments in which each line has the form,

left_formula & *middle_formula* & *right_formula* .

For example,

```
\begin{eqnarray}
\parallel m \parallel^2 & = & \alpha \cdot \Gamma \alpha \nonumber \\
& = & \alpha \cdot \Sigma (\Sigma^{-1} \Gamma \Sigma^{-1}) \Sigma \alpha \nonumber\\
& = & \mathbf{x} \cdot A \mathbf{x}
\end{eqnarray}
```

produces

$$\begin{aligned} \parallel m \parallel^2 &= \alpha \cdot \Gamma \alpha \\ &= \alpha \cdot \Sigma\, (\Sigma^{-1} \Gamma\, \Sigma^{-1})\, \Sigma\, \alpha \\ &= \mathbf{x} \cdot A\, \mathbf{x} \end{aligned} \tag{2}$$

Note here the use of the \nonumber command to suppress equation numbering on the first two lines of the eqnarray.

4.4.4 Framing an equation

To place a frame around an important equation, enclose the formula text with the \fbox command, as in:

```
\begin{equation}
\fbox{$ \delta[m] = \parallel \Sigma^{-1} (\mathbf{d} - \mathbf{F}[m]) \parallel_2 $}
\end{equation}
```

which produces,

$$\boxed{\delta[m] = \parallel \Sigma^{-1}(\mathbf{d} - \mathbf{F}[m]) \parallel_2} \tag{3}$$

Note here that we have to include $ symbols around the formula text.

A more robust way to accomplish this that gives more control over the size of the frame is to use the \parbox command in conjunction with the \fbox command,

```
\begin{equation}
\fbox{\parbox[c][1cm][c]{6.5cm}{\[ \delta[m] = \parallel \Sigma^{-1} (\mathbf{d} - \mathbf{F}[m])
\parallel_2 \] }}
\end{equation}
```

which gives,

$$\boxed{\delta[m] = \parallel \Sigma^{-1}(\mathbf{d} - \mathbf{F}[m]) \parallel_2 .} \tag{4}$$

In the \parbox command above, \[and \] are shorthand for \begin{displaymath} and \end{displaymath}, respectively.

5 Cross-Referencing

For each document, LaTeX automatically keeps track of section, equation, table, figure, footnote, and citation numbers through the use of internal counters. This makes it easy to cross-reference sections, tables, figures, etc. within a document using the pair of commands,

\label{*name*} \ref{*name*}

where *name* is the name you have given to the reference. For example, consider an equation describing the thermal conductivity of ice,

$$K_i(T) = a_1 \exp(-a_2 T) \tag{5}$$

produced by,

```
\begin{equation}
K_i(T) = a_1 \exp \left( -a_2 T \right)        \label{eq:Kice}
\end{equation}
```

To refer to this equation later on in the text, simply issue the command \ref{eq:Kice} at the location you want the equation number to appear, e.g., "The thermal conductivity of ice is given by Equation~\ref{eq:Kice}". The typeset version of this sentence is "The thermal conductivity of ice is given by Equation 5". Similarly, a figure, table, or section can be referenced in the text if the \label command has been issued along with the \figure, \table, or \section commands.

Although the label *name* can be any combination of letters, numbers, or symbols, a useful mnemonic is to begin the names with sec: for sections, eq: for equations, fig: for figures, and ta: for tables.

6 Tables

LaTeX provides three environments for constructing tables and matrices:

\begin{array}[*pos*]{*cols*}	*rows*	\end{array}
\begin{tabular}[*pos*]{*cols*}	*rows*	\end{tabular}
\begin{tabular*}[*pos*]{*cols*}	*rows*	\end{tabular*}

The array environment is reserved for displaying mathematical material and thus can only be used in math mode. The two tabular environments are the same except for a two-column formatted document such as a journal article. In this case, tabular* will produce a table that stretches across both columns. The optional parameter *pos* can take on values of t or b, which informs LaTeX to align the top or bottom line of the table with the current baseline. The default is to center the table on the current baseline. Argument *cols* is used to indicate whether the contents of a column should be (l)eft, (c)enter, or (r)ight justified; there must be one entry for every column. Thus, to produce a table with two left-justified columns, a centered column, and a right-justified column, *cols* would be llcr. *rows* are the actual rows of the table. Column entries within a row are separated by & symbols and the row is terminated by \\, although the last row need not be.

LaTeX has many options and commands for building complicated tables but few of them are used in tables destined for scientific journals. The most important ones for scientific reports are:

\hline	draw a horizontal line across the width of a table.
\cline{*n*–*m*}	draw a horizontal line from the left side of column *n* to the right side of column *m*.
\multicolumn{*num*}{*col*}{*text*}	print *text* across *num* columns. *col* indicates if the text should be (l)eft, (c)entered, or (r)ight justified within the space.

A few examples will clarify some of these ideas. The first is for a simple two-column mathematical table in which the first column is right-justified while the second is centered,

```
\begin{displaymath}          % enter math mode
```

```
\begin{array}{rc}
  -1, & x < 0 \\
  0, & x = 0 \\
  1, & x > 0 \\
\end{array}
\end{displaymath}                % exit math mode
```

which produces,

$$\begin{array}{rc}
  -1, & x < 0 \\
  0, & x = 0 \\
  1, & x > 0 \\
\end{array}$$

Note that the columns do not need to be aligned in the *.tex document. LaTeX automatically aligns the columns during typesetting. The following example shows the use of the hline command to delineate portions of the table, as well as the cline and multicolumn commands to produce the column headings:

```
\begin{tabular}{ccrll}
  \hline
  & \multicolumn{2}{c}{$c_{pl}$} & & $c_{pi}$ \\   \cline{2-3} \cline{5-5}
  $i$ & $a_i$ & $b_i$ & & $a_i$ \\
  \hline
  1 & 3791.4 & 4178.9 & & 2096.1 \\
  2 & 75.457 & 2.2374 & & 1943.8 \\
  3 & & 1509.5 \\
  4 & & $-$7129.5 \\
  5 & & 19923 \\
  \hline
\end{tabular}
```

which produces,

	c_{pl}			c_{pi}
i	a_i	b_i		a_i
1	3791.4	4178.9		2096.1
2	75.457	2.2374		1943.8
3		1509.5		
4		-7129.5		
5		19923		

In this example, a fourth column without any content was introduced to produce a gap between the lines underlying the headings c_{pl} and c_{pi}.

In the above examples, the tables appear on the page right where the \begin{tabular} - \end{tabular} commands occur. Journals generally prefer to place tables at the top or bottom of a page, or at the top or bottom of a column in two-column format. To accomplish this, embed the table within a table environment,

\begin{table}[*where*]	*table*	\end{table}
\begin{table*}[*where*]	*table*	\end{table*}

Use the *-form if the table is to stretch across both columns of a two-column formatted document. Argument *where* indicates where the table should be placed: (1) At the (t)op of the current page if there's room, if not float it to the top of the next page. (2) At the (b)ottom of the current page if there's room, if not float it to the bottom of the next page. (3) Put it on a special (p)age reserved for just tables and/or figures. Note that this floating mechanism will carry a caption, if there is one, along with the table.

To provide a caption insert the \caption{*text*} command between the \begin{table} and \begin{tabular} commands as in the following example,

```
\begin{table}[t]
\caption{Coefficients $a_i$ and $b_i$ for the specific heat of liquid water and of ice ($c_{pl}$ and
$c_{pi}$ in J kg$^{-1}$ K$^{-1}$).}
\label{ta:cp_coefs}
\begin{tabular}{ccrll}
  \hline
  & \multicolumn{2}{c}{$c_{pl}$} & & $c_{pi}$ \\   \cline{2-3} \cline{5-5}
  $i$ & $a_i$ & $b_i$ & & $a_i$ \\
  \hline
  1 & 3791.4 & 4178.9 & & 2096.1 \\
  2 & 75.457 & 2.2374 & & 1943.8 \\
  3 & & 1509.5 \\
  4 & & $-$7129.5 \\
  5 & & 19923 \\
  \hline
\end{tabular}
\end{table}
```

Note the inclusion of the \label command so that the table can be referred to in the text. The typeset result for this table is,

Table 1: Coefficients a_i and b_i for the specific heat of liquid water and of ice (c_{pl} and c_{pi} in $\mathrm{J\,kg^{-1}\,K^{-1}}$).

	c_{pl}		c_{pi}
i	a_i	b_i	a_i
1	3791.4	4178.9	2096.1
2	75.457	2.2374	1943.8
3		1509.5	
4		−7129.5	
5		19923	

7 Packages

The user community has developed hundreds of packages that extend the capabilities of standard LaTeX. These packages change the ways certain commands behave and/or add new commands to provide additional features. Some of the more common packages are:

amsmath	provides advanced math extensions
amssymb	adds new math symbols
babel	provides language support for languages other than english
biblatex	provides advanced bibliographic handling
caption	provides customization of captions for figures and tables
chemmacros	a collection of macros to support typesetting chemistry documents
graphicx	allows for the insertion of a variety of graphic file formats
hyperref	allows LaTeX to manage links within a document
natbib	gives additional citation options and styles
subcaption	provides subcaptions for subfigures
xcolor	adds support for colored text

A more complete list can be found at https://en.wikibooks.org/wiki/LaTeX/Package_Reference and at the Comprehensive TeX Archive Network (https://www.ctan.org) where LaTeX packages can also be downloaded[§]. Once a package has been downloaded, it can be accessed by including the \usepackage{*package_name*} command in the document's preamble. For example,

```
\usepackage{graphicx, natbib}
```

will tell LaTeX to use the graphicx and natbib packages. Because of interactions between packages, sometimes they won't work correctly unless they are imported into LaTeX in a certain order. For example, hyperref often works best if it is the last package imported with the \usepackage command.

A word of caution for journal manuscripts. Journal's typically use only a limited number of packages which they automatically access through their class (*.cls) files. They generally request

[§]By convention, LaTeX packages are given the filename extension *.sty

that authors not include additional packages. Read a journal's latex instructions for authors carefully before assuming you can use the enhancements provided by a package. Every journal is different. It is very common for journals to include (or allow the use of) the graphicx and natbib packages. For dissertations there are no restrictions on which packages you utilize.

8 Figures

The easiest and most widespread way to include a figure or image in a document is to use the graphicx package. Once graphicx has been downloaded to your computer, include the \usepackage{graphicx} command in the document's preamble. With graphicx, it's possible to insert a variety of graphic formats (*.eps, *.pdf, *.png, *.jpg, ...) into a document using the command,

\includegraphics[*options*]{*filename*}

A wide range of *options* are available with the \includegraphics command. However, the following will almost always produce a successful result,

\includegraphics[width=Xmm,trim=Lmm Bmm Rmm Tmm,clip]{*filename*}

where X is the width of the printed figure and trim is used to crop any excess white border present in the original graphics file; *L, B, R, T* are the number of mm to crop on the left, bottom, right, and top sides of the figure, respectively. As always with LaTeX, feel free to use any appropriate units you wish (e.g., mm, cm, in, pt, bp, pc, dd, cc, em, ex).

A good practice is to float figures to the top or bottom of a page. In fact, most journals will require this. To float a figure, embed the \includegraphics command within the \begin{figure}[*where*] - \end{figure} environment. Option *where* is the same as for the table environment, e.g., t, b, p places the figure at the top or bottom of a page, or on a page reserved for figures and tables. Sometimes a figure won't appear where you expect. To encourage LaTeX to place the figure (or table) where you want, try following the *where* parameter with a ! symbol. For example, to place a graphic figure pore_conductivity.eps at the top of a page, crop the excess white border present in the *.eps file, include a caption, and label the figure fig:Kpore for later referencing, consider:

```
\begin{figure}[t!]
\includegraphics[width=83mm,trim=12mm 1mm 22mm 13mm,clip]{pore_conductivity.eps}
\caption{Variation of the pore thermal conductivity $k_p$ on Earth at $-10^\circ$C with the relative volume fractions of liquid water ($\psi_\ell$), ice ($\psi_i$), and air ($\psi_a$) within the pores.}
\label{fig:Kpore}
\end{figure}
```

The typeset version of this figure appears on the next page.

To stretch a large figure across two columns in a two-column formatted document such as a journal article, use the *-form of the figure environment, \begin{figure*}[*where*] - \end{figure*}.

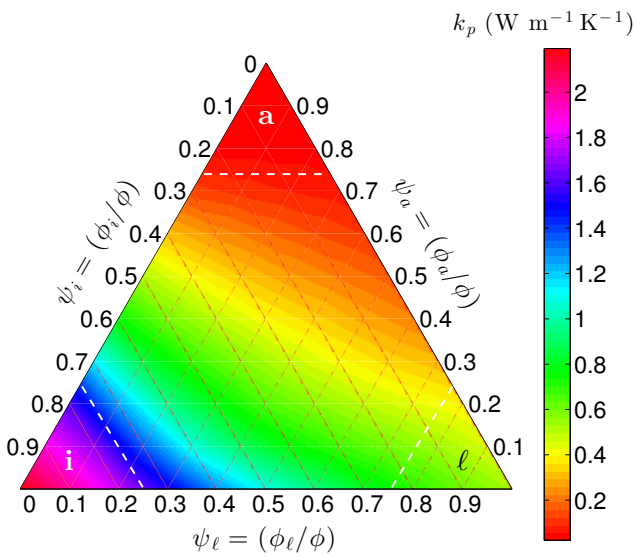

Figure 1: Variation of the thermal conductivity of soil pore spaces k_p on Earth at $-10°$C with relative volume fractions of liquid water (ψ_ℓ), ice (ψ_i), and air (ψ_a) within the pores.

9 Bibliographies

There are two approaches for creating bibliographies. The first is to provide all the references at the end of a document, while the second is to access references from a user-created database.

9.1 Self-contained references

Listing all the references at the end of a document is the simplest approach for creating a bibliography. To create the bibliography, use thebibliography environment at the place in the document where you want the bibliography to appear. The syntax is,

\begin{thebibliography}{*sample_label*}
  \bibitem[*cite_label*]{*cite_key*} *citation_text*
  \bibitem[*cite_label*]{*cite_key*} *citation_text*
  ⋮
\end{thebibliography}

where *sample_label* indicates how much space to reserve for indenting citations. For example, to create an indentation the width of the characters 99, let *sample_label*=99. Optional argument *cite_label* shows how the citation should appear in the text; if no argument is given, the citation is numbered sequentially. Argument *cite_key* is the user-selected reference keyword while *citation_text* is the citation as it is to appear in the bibliography. For example,

```
\begin{thebibliography}{99}
\bibitem{anderson84} Anderson, D.A., Tannehill, J.C., and Pletcher, R.H.: Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corp., New York, 599~pp., 1984.
\bibitem{angell82} Angell, C.A., Oguni, M., and Sichina, W.J.: Heat capacity of water at extremes of supercooling and superheating, J.~Phys.\ Chem, 86, 998--1002, 1982.
\end{thebibliography}
```

produces,

References

(1) Anderson, D.A., Tannehill, J.C., and Pletcher, R.H.: Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corp., New York, 599 pp., 1984.

(2) Angell, C.A., Oguni, M., and Sichina, W.J.: Heat capacity of water at extremes of supercooling and superheating, J. Phys. Chem, 86, 998–1002, 1982.

Note that the heading **References** is created automatically. To cite a reference anywhere in the text, simply use the \cite{*cite_key*} command. For instance, \cite{angell82} produces Angell et al. (1982).

9.2 Natbib

The natbib package re-implements the native LaTeX \cite command, giving it much greater flexibility. Scientific journals commonly use natbib. To utilize the natbib package, first import it in the preamble with the \usepackage[*options*]{natbib} command where some of the options are:

round	use round parentheses in citations (default)
square	use square brackets
curly	use curly brackets
colon	separate multiple citations with semicolons (default)
comma	separate multiple citations with commas
authoryear	for author-year citations (default)
numbers	for numerical citations
super	use superscripted numerical citations

Package natbib introduces two new commands,

\citet[*before*][*after*]{*key*}	to cite a reference as part of the text
\citep[*before*][*after*]{*key*}	to place parentheses around the citation

Optional arguments *before* and *after* allow text to be inserted before or after the citation. For multiple citations, simply list them separated by commas within the \citet and \citep commands.

As an example, suppose we want the author-year citation style with round parentheses and semicolon separators for multiple citations. In this case, the natbib defaults are fine. Returning to the above example, the only thing we need to change to implement the author-year style are the *cite_labels*,

```
\setlength{\bibsep}{0.5ex}
\begin{thebibliography}{}
\bibitem[Anderson et al.(1984)]{anderson84} Anderson, D.A., Tannehill, J.C., and Pletcher, R.H.: Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corp., New York, 599~pp., 1984.
\bibitem[Angell et al.(1982)]{angell82} Angell, C.A., Oguni, M., and Sichina, W.J.: Heat capacity of water at extremes of supercooling and superheating, J.~Phys.\ Chem, 86, 998--1002, 1982.
\end{thebibliography}
```

This produces,

References

Anderson, D.A., Tannehill, J.C., and Pletcher, R.H.: Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corp., New York, 599 pp., 1984.

Angell, C.A., Oguni, M., and Sichina, W.J.: Heat capacity of water at extremes of supercooling and superheating, J. Phys. Chem, 86, 998–1002, 1982.

The optional parameter *bibsep* was reset here to reduce the separation between the bibliographic items; natbib's default is to insert a blank line between bibitems.

Examples of citations with natbib include:

\citet{anderson84}	Anderson et al. (1984)
\citep{anderson84}	(Anderson et al., 1984)
\citet{anderson84, angell82}	Anderson et al. (1984); Angell et al. (1982)
\citep{anderson84, angell82}	(Anderson et al., 1984; Angell et al., 1982)
\citep[see][]{angell82}	(see Angell et al., 1982)
\citep[][chapter 5]{anderson84}	(Anderson et al., 1984, chapter 5)
\citep[see][chapter 5]{anderson84}	(see Anderson et al., 1984, chapter 5)

9.3 BibTeX

BibTeX is an auxiliary tool that comes bundled with LaTeX that allows references to be stored in an external flat-file database. Although this requires some effort to setup, in the long-run it may be advantageous if you know you will be citing the same references in more than one document. In addition, journals often provide a bibliographic style (*.bst) file that will allow LaTeX to automatically sort and format the references in their particular style.

9.3.1 BibTeX database

A BibTeX database is a user-created plain text file with the extension *.bib. Each entry consists of a reference type (@*reference_type*) followed by several keywords and their values. Reference types include: article, book, inbook, proceedings, inproceedings, mastersthesis, phdthesis, and others. The

required keywords depend on the reference type (see https://en.wikibooks.org/wiki/LaTeX/Bibliography_Management). As an example, consider the sample database file mysample.bib:

```
@article{angell82,
    author = "Angell, C.A. and Oguni, M. and Sichina, W.J.",
    title = "Heat capacity of water at extremes of supercooling and superheating",
    journal = "J.~Phys.\ Chem",
    volume = "86",
    pages = "998--1002",
    year = "1982"
    }

@article{rothschild01,
    author = "Rothschild, L.J. and and Mancinelli, R.L.",
    title = "Life in extreme environments",
    journal = "Nature",
    volume = "409",
    pages = "1092--1101",
    doi = "10.1038/35059215",
    year = "2001"
    }

@book{anderson84,
    author = "Anderson, D.A. and Tannehill, J.C. and Pletcher, R.H.",
    title = "Computational Fluid Mechanics and Heat Transfer",
    publisher = "Hemisphere Publishing Corp.",
    pages = "599",
    year = "1984"
    }

@inproceedings{anderson73,
    author = "Anderson, D. M. and Tice, A.R. and McKim, H.L.",
    title = "The unfrozen water and the apparent specific heat capacity of frozen soils",
    booktitle = "Proceedings of the Second International Conference on Permafrost",
    year = "1973",
    month = "July",
    pages = "289--295",
    address = "Yakutsk, USSR"
    }
```

The syntax is,

$$
\begin{aligned}
&@reference_type\{cite_key,\\
&\quad keyword1 = "value",\\
&\quad keyword2 = "value",\\
&\qquad\quad \vdots\\
&\quad keywordN = "value"\\
&\quad \}
\end{aligned}
$$

Note that values are surrounded by the double-quote symbol and that all the keyword lines are terminated by a comma, although the last one need not be. Also, each reference is terminated by a right curly bracket } to denote the end of the reference. The references do not need to be sorted as LaTeX will do that when creating the bibliography. Also note that authors are separated by the

connecting word 'and' on the author keyword line rather than by a comma. Finally, be sure that each *cite_key* in the database is unique.

9.3.2 Using BibTeX with LaTeX

Importing references into a LaTeX document from a database with BibTeX is a little involved but it's not too bad once you get used to it.

Step 1: The first step is to add the two commands,

\bibliographystyle{*bibstyle_file*}
\bibliography{*data_file*}

at the location where the bibliography is to appear in your document. These commands replace thebibliography environment. The \bibliographystyle command informs LaTeX which bibliographic style (*.bst) file to use. The following style files typically come bundled with BibTeX: abbrv.bst, acm.bst, alpha.bst, apalike.bst, ieeetr.bst, plain.bst, siam.bst, unsrt.bst. See https://www.overleaf.com/learn/latex/Bibtex_bibliography_styles for typeset style examples. If a numerical citation scheme is desired, plain.bst does a surprisingly good job. Journals will often provide their own bibliographic style file, e.g., Copernicus Publications provides the file copernicus.bst for its journals.

The \bibliography command tells LaTeX which *.bib data file to use for the references; the file extension .bib need not be included as it is assumed. If you have more than one bibliographic database, for instance a *.bib file for glaciers and another one for permafrost, you can list them both separated by a comma but no white space, e.g., \bibliography{glaciers,permafrost}. If the *.bib files are in a directory other than the one with the LaTeX document, you will need to include the path, e.g., \bibliography{~/mybib_databases/glaciers,~/mybib_databases/permafrost}.

Step 2: Run LaTeX on your document. Suppose it's called mydoc.tex. In this case, running LaTeX will add citation information to an auxiliary file called mydoc.aux.

Step 3: Run BibTeX on the document mydoc.tex. BibTeX will examine the mydoc.aux file for citations, extract the relevant information from the data (*.bib) files, and create a new file mydoc.bbl that contains only the bibliographic information for the references cited in mydoc.tex. This information is formatted according the style specified in the style (*.bst) file.

Step 4: Run LaTeX twice more on mydoc.tex so that it can extract the information from the *.bbl file and update any missing information.

As you incorporate additional citations into a document, Steps 1–4 will need to be repeated to update the referencing information.

As usual, the \cite command can be used to provide citations within the text of a document. However, BibTeX works nicely with the natbib package, allowing the use of \citet and \citep. The combination of BibTeX and natbib provides the enhanced flexibility of natbib with the convenience of a bibliographic database.

As an example, suppose we've imported the natbib package and included the following commands in the LaTeX document,

```
\bibliographystyle{copernicus}
\bibliography{mysample}
```

If we now cite (Angell et al., 1982; Anderson et al., 1984; Rothschild et al., 2001), those references will appear in the bibliography in the style specified by copernicus.bst. The proceedings reference by Anderson et al. (1973) in mysample.bib doesn't appear in the bibliography because it hasn't been cited in the document.

References

Anderson, D., Tannehill, J., and Pletcher, R.: Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corp., 1984.

Angell, C., Oguni, M., and Sichina, W.: Heat capacity of water at extremes of supercooling and superheating, J. Phys. Chem, 86, 998–1002, 1982.

Rothschild, L., , and Mancinelli, R.: Life in extreme environments, Nature, 409, 1092–1101, https://doi.org/10.1038/35059215, 2001.

9.4 BibLaTeX

BibTeX has been around a long time. A more modern bibliographic database tool utilizing the LaTeX macro language is provided by the BibLaTeX package. For compatibility, it uses the same bibliographic data (*.bib) files as BibTeX. The difference is in the commands.

To use BibLaTeX, first import the package and the data (*.bib) files in the preamble using the \usepackage[*options*]{biblatex} and \addbibresource{*data_file*} commands. BibLaTeX options include: backend, style, and sorting. Possible values include:

backend= biber, bibtex
style= numeric, alphabetic, authoryear, authortitle, verbose, reading, draft
sorting= nyt, ynt, ... (where n is name, y is year, t is title)

Backend determines how the bibliography is sorted (biber is usually a good choice). Suppose we want to use the authoryear style, name-year-title sorting, and our mysample.bib data file. The corresponding commands in the preamble would be:

```
\usepackage[backend=biber,style=authoryear,sorting=nyt]{biblatex}
\addbibresource{mysample}
```

Finally, to print the bibliography at the desired location in the document, issue the command,

```
\printbibliography
```

One caution about BibLaTeX is that most journals still rely on BibTeX and natbib. At the moment, BibLaTeX does not appear to be an option for most journal articles.

10 Hyperlinks

It's easy to create hyperlinks between cross-references within a document using the hyperref package. This package normally works best if it is the last package imported by LaTeX with the \usepackage command. Once hyperref has been imported, LaTeX will automatically establish clickable links in the typeset (*.pdf) document for all cross-referenced items such as sections, tables, figures, equations, and citations. Links to websites can be established using the \url{*web_address*} command, e.g., \url{https://www.ctan.org}. An nice feature of the \url command is that special LaTeX characters such as _ do not need to be preceded with a backslash in order to be printed or displayed. Links to local files can also be established using the \href{run:*path/filename*}{*displayed_text*} command. Here, *path* is the absolute or relative path to the file on the same computer as the LaTeX document, *filename* is the name of the file, and *display_text* is the text that's displayed in the *.pdf file. For example, \href{run:./hyperref_manual.pdf}{Hyperref User's Manual} produces a clickable link to the Hyperref User's Manual in the typeset document.

By default, hyperlinks are black. To use hyperref's default color scheme, insert the \hypersetup {colorlinks=true} command after the \usepackage{hyperref} command in the preamble. You can override the default colors to make them easier to see. For example, this document uses:

\hypersetup{colorlinks=true, linkcolor=blue, citecolor=green, filecolor=red, urlcolor=cyan}

The use of the hyperref package is permitted for CU dissertations. However, in order for a dissertation to be self-contained, the Graduate School doesn't allow linking to outside the document, i.e., to websites or local files. Internal hyperlinking to facilitate cross-referencing within the dissertation is allowed.

11 Track changes

When several authors are writing a collaborative document, it's useful to track author changes as the document circulates. For LaTeX documents, there are at least three different approaches for tracking changes: (1) use the TrackChanges package for LaTeX, (2) use a tool such as Adobe Acrobat Pro to markup the PDF file, and (3) use an online service such as Overleaf that includes a track changes tool[¶]. Here, we'll discuss just the first approach although the others are equally valid.

To use the LaTeX TrackChanges package:

Step 1: Download TrackChanges and import it in the preamble using the command \usepackage[*options*] {trackchanges}. The *options* include,

margins	display the edits in the margins
inline	display the edits inline
footnotes	display the edits as footnotes
finalold	reject all the edits for the typeset PDF
finalnew	accept all the edits for the typeset PDF

[¶]For more information about the Overleaf track changes tool, go to https://www.overleaf.com/learn/how-to/Track_Changes_in_Overleaf.

Step 2: Add the authors in the preamble using the \addeditor{*author*} command, e.g.,

```
\addeditor{gc}      % gary
\addeditor{io}      % irina
\addeditor{kw}      % kang
\addeditor{tg}      % tian
```

Step 3: Make edits in the body of the paper using the following commands,

```
\add[author]{text to add}
\remove[author]{text to remove}
\change[author]{text to remove}{text to add}
\note[author]{the note}
\annote[author]{text to annotate}{the note}
```

For example, consider the following paragraph:

"Current understanding of the interactions between weather, climate, permafrost, and hydrology remains inadequate due to the lack of hydrometric measurements in cold regions. We ask how permafrost conditions are different within floodplain corridors as compared to the surrounding environment. Together with earlier snowmelt, Arctic rivers have exhibited trends toward earlier river breakups and later river freeze-up dates, reduced ice-cover duration, and increasing discharge and water temperature."

While circulating the paragraph among the authors, several changes were suggested using the TrackChanges editing commands. These are shown here using the margins option:

[c1] *gc*: *Text added.*
[c2] *io*: ~~weather~~
[c3] *kw*: *Text added.*
[c4] *tg*: ~~We~~
[c5] *io*: ~~s~~

"Current understanding of the [c1]complex interactions between [c2] climate, permafrost, and hydrology remains inadequate due to the lack of [c3]climatic and hydrometric measurements in cold regions. [c4]Here, we ask how permafrost conditions are different within floodplain corridors as compared to the surrounding environment. Together with earlier snowmelt, Arctic rivers have exhibited trends toward earlier river breakup[c5] and later river freeze-up dates, reduced ice-cover duration, and increasing discharge and water temperature."

The authors jointly agreed to accept all the changes. Leaving the editing commands in place but changing option margins to finalnew, the typeset paragraph becomes:

"Current understanding of the complex interactions between climate, permafrost, and hydrology remains inadequate due to the lack of climatic and hydrometric measurements in cold regions. Here, we ask how permafrost conditions are different within floodplain corridors as compared to the surrounding environment. Together with earlier snowmelt, Arctic rivers have exhibited trends toward earlier river breakup and later river freeze-up dates, reduced ice-cover duration, and increasing discharge and water temperature."

The TrackChanges tool also offers a GUI (trackchanges.py) for accepting or rejecting edits. For more information about the TrackChanges package and the associated GUI, go to: http://trackchanges.sourceforge.net.

12 Theses and Dissertations

Being a larger body of work, Master's theses and Doctoral dissertations differ from journal articles in that they normally include a prologue listing the author, degree, department, advisor, committee members (or readers), a table of contents, a list of figures, and a list of tables. The body of the dissertation consists of chapters, followed by the bibliography and an optional appendix.

A university's style (*.cls) file will typically define new commands, e.g., to list the degree and department, while disabling or modifying other LaTeX commands. Among other things, the page size and margins will be set by the university's *.cls file. The style file is generally based on the book class although some university's base it on the report class. The University of Colorado's *.cls file has several options. A good starting point is to use the defaultstyle and 11pt,

```
\documentclass[defaultstyle,11pt]{thesis.cls}
```

The inclusion of packages in a thesis is normally fine but because of interactions between packages, the order in which the packages are imported in the preamble may be important. This may take some experimentation. At the very least, the packages graphicx, natbib, and hyperref are recommended.

Generating the table of contents, list of figures, and list of tables is easy with LaTeX. Simply insert the commands \tableofcontents, \listoffigures, \listoftables in the prologue. LaTeX will use its built-in counters to construct the lists.

Although it's possible to write a thesis or dissertation as one massive LaTeX document, it's usually more convenient to write the chapters as separate documents. A reasonable organizational strategy is to place each chapter (*.tex file) and associated figures in their own subdirectory under the main thesis directory, e.g.,

```
\mythesis
    mythesis.tex
    \abstract
        abstract.tex
    \introduction
        intro.tex
    \chap1
        methodsA.tex
        \figures
    \chap2
        methodsB.tex
        \figures
    \chap3
        analysisA.tex
        \figures
```

```
\chap4
    analysisB.tex
    \figures
\chap5
    implications.tex
    \figures
\summary
    summ.tex
\bibliography
    mythesis.bib
```

Pulling a chapter into the main document can be done using the \include{*path/sub-document*} command, e.g., \include{introduction/intro.tex}. Thus, the structure of the main document (e.g., mythesis.tex) might look like,

```
\documentclass[defaultstyle,11pt]{thesis.cls}
\usepackage{graphicx}
\usepackage{natbib}
\usepackage{hyperref}
\hypersetup{colorlinks=true, linkcolor=blue, citecolor=green}
    ⋮
\begin{document}
    ⋮
\tableofcontents
\listoffigures
\listoftables
\include{introduction/intro.tex}
\include{chap1/methodsA.tex}
\include{chap2/methodsB.tex}
\include{chap3/analysisA.tex}
\include{chap4/analysisB.tex}
\include{chap5/implications.tex}
\include{summary/summ.tex}
\include{bibliography/bibliog.tex}
\end{document}
```

The sub-documents pulled into the main document have a very simple form. They begin with the command \chapter[*short_title*]{*chap_title*} and then the text follows, e.g.,

```
\chapter[Thermophysical Properties]{Thermophysical Properties of Permafrost}
                                    ⋮
```

chapter text

The *short_title* is what appears in the table of contents while *chap_title* is what is printed at the beginning of the chapter. In most cases, they should be the same. Of more use in a dissertation is the extended form of the \caption[*short_caption*]{*text*} command used for figures and tables. Here, *short_caption* is what appears in the list of figures and list of tables while *text* is the actual caption.

For more specific information about using LaTeX for CU theses and dissertations, see https://oit.colorado.edu/software-hardware/tex-latex/thesis-class. CU's thesis.cls file can be downloaded from this site.

13 Resources

13.1 LaTeX overview and tutorials

https://www.latex-project.org Official LaTeX website.

https://en.wikibooks.org/wiki/LaTeX Wiki guide to LaTeX.

https://www.andy-roberts.net/writing/latex Beginners' tutorials for LaTeX.

https://www.latex-tutorial.com Short tutorials for LaTeX.

https://www.overleaf.com Introduction to the Overleaf project system for LaTeX.

https://www.overleaf.com/learn/latex/Tutorials A comprehensive set of LaTeX tutorials.

13.2 User's groups

http://tug.org TeX User's Group

13.3 Where to get LaTeX

https://pages.uoregon.edu/koch/texshop TeXShop: easy to use and install version for Mac

http://www.tug.org/mactex MacTeX: comprehensive LaTeX system for Mac, includes TeXShop

https://ctan.org/pkg/protext ProTeXt: easy to install version for Windows

https://www.overleaf.com Overleaf: Online version of LaTeX, nothing to install, requires a subscription

13.4 Packages

https://en.wikibooks.org/wiki/LaTeX/Package_Reference Wiki guide to LaTeX packages.

https://www.ctan.org Comprehensive Archive: The place to go to obtain LaTeX packages.

13.5 Bibliographies

https://en.wikibooks.org/wiki/LaTeX/Bibliography_Management Wiki guide to creating LaTeX bibliographies.

https://en.wikipedia.org/wiki/BibTeX Wiki guide to BibTeX.

https://www.overleaf.com/learn/latex/Bibliography_management_in_LaTeX Overleaf guide to BibLaTeX and more.

13.6 Track changes

http://trackchanges.sourceforge.net TrackChanges package.

https://www.overleaf.com/learn/how-to/Track_Changes_in_Overleaf Information about track changes using Overleaf.

13.7 Journal resources

https://publications.agu.org/author-resource-center/text-requirements/latex-guidelines AGU LaTeX guidelines.

https://publications.copernicus.org/for_authors/manuscript_preparation.html] Copernicus LaTeX guidelines.

13.8 CU dissertations

https://oit.colorado.edu/software-hardware/tex-latex Overview of LaTeX.

https://oit.colorado.edu/software-hardware/tex-latex/thesis-class Documentation and download site for the CU LaTeX dissertation style file (thesis.cls), as well as sample LaTeX thesis files.