Introduction to LaTeX

2017

By
Maksims Abaļenkovs
m.abalenkovs@manchester.ac.uk

Contents

Chapter 1

Introduction to LaTeX

1.1 Plan of the Day

9:30–11:00	Introduction to LaTeX
11:00–12:30	Mathematics in LaTeX
13:00–14:30	Graphics and tables
14:30–16:00	Bibliography management
16:00–16:30	LaTeX style files: `muthesis`, `IEEEtran`

1.2 Why LaTeX?

- Extensive support of mathematical notation
- Article templates for IEEE, SIAM, ...
- Professional (beautiful) look of documents
- Predefined document classes
- High amount of custom functionality provided with packages
- User-defined notation
- Word hyphenation
- Content separation from layout
- Interactive cross-referencing (hyperref)
- Flexible and powerful bibliography management (BibTeX)

1.3 What is LaTeX?

- Text markup and programming language (HTML analogy)
- Compilation approach opposite to WYSIWYG
- Content ↔ Layout
- Elements are positioned with commands and environments
- Authors: Donald Knuth [4], Leslie Lamport [5]
- Pronunciation: "X" as in *loch* or *Bach*
- Meaning: TeX abbr. for "techne", Greek for "art", "craft", root of word "technical"

1.4 How Does LaTeX Work?

- Three steps: Edit → Compile → View
- Source file `*.tex` is created by user in a text editor
- Source file is compiled with LaTeX or PDFLaTeX
- Resulting file in DVI, PS or PDF format is viewed with a file viewer

1.5 LaTeX Command and LaTeX Environment

1.5.1 Command

```
\command[options]{arguments}
```

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

- Commands begin with the backslash symbol "\"
- Command names are case-sensitive

1.5.2 Environment

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

```
\begin{document}
...
\end{document}
```

1.6 Minimal Document

```
\documentclass{article}

\begin{document}
  The truth is out there...
\end{document}
```

1.7 Typical Document Structure

```
\documentclass{...}      % preamble

\usepackage{...}         % package inclusion

\begin{document}         % top matter

\title{...}
\author{...}
\date{...}

\maketitle

\section{...}            % main body
\subsection{...}

\appendix                % appendices
\section{...}
\subsection{...}

\bibliographystyle{...}  % bibliography
\bibliography{...}

\end{document}
```

1.8 Main Document Classes

```
\documentclass{article}
```

`article`	scientific articles, generic publications
`IEEEtran`	articles in IEEE Transactions
`report`	reports, documents > articles
`book`	books, documents > reports ≫ articles (even/odd pages)
`beamer`	presentations, lecture notes, handouts
`sciposter`	scientific posters (columns, portrait, landscape)
`muthesis`	BSc, MSc, PhD theses, UoM
`letter`	letters (address, signature)

1.9 Document Class Options

```
\documentclass[10pt,a4paper,twocolumn,twoside,draft]{article}
```

`10pt`	font size
`a4paper`	A4 paper size
`twocolumn`	two column
`twoside`	double sided (page numbers, margins, headers)
`draft`	draft version (no images, err. hyphenation, justification)

1.10 Sectioning Commands

- `\part{...}` book only
- `\chapter{...}` book, report only
- `\section{...}`
- `\subsection{...}`
- `\subsubsection{...}`
- `\paragraph{...}`
- `\subparagraph{...}`
- No sectioning commands in the `letter` class
- Optional short title with `\section[...]{...}`
- Unnumbered section with `\section*{...}`

1.11 Cross-Referencing

- Cross-referencing any numbered element
  (equation, theorem, figure, listing, section, page)
- Label an element with `\label{S:intro}`
- Refer to an element with `\ref{S:intro}`
- Denote element types in labels explicitly with `C, S, T, F, E`
- Use unbreakable space "~" before the reference `~\ref{S:intro}`

1.12 Example of Cross-Referencing

```
\section{Introduction}
\label{S:intro}

\section{Summary}
\label{S:summary}

Section~\ref{S:intro} provides a concise introduction.
```

1.13 Type Faces

Syntax	Example	Result
`\textrm{...}, {\rm ...}`	`{\rm Roman}`	Roman
`\textbf{...}, {\bf ...}`	`{\bf Bold Face}`	**Bold Face**
`\textit{...}, {\it ...}`	`{\it Italic}`	*Italic*
`\textsl{...}, {\sl ...}`	`{\sl Slanted}`	*Slanted*
`\textsf{...}, {\sf ...}`	`{\sf Sans Serif}`	Sans Serif
`\texttt{...}, {\tt ...}`	`{\tt True Type}`	`True Type`
`\textsc{...}, {\sc ...}`	`{\sc Small Caps}`	SMALL CAPS

- Curly brackets "{" and "}" limit the scope of a command
- Use the `\emph{}` command to emphasize:

  `All mass is \emph{interaction.}` → All mass is *interaction.*

1.14 Verbatim

- Short (inline) verbatim with `\verb|...|`

```
Special characters in \LaTeX{} include \verb|# $ % ^ & _ { } ~ \|.
```

Special characters in LaTeX include `# $ % ^ & _ { } ~ \`.

```
In MATLAB matrices may be initialised
with functions \verb|zeros()|, \verb|ones()| or \verb|rand()|.
```

In MATLAB matrices may be initialised with functions `zeros()`, `ones()` or `rand()`.

- Long verbatim with the `verbatim` environment

```
\begin{verbatim}
  Z = zeros(1,5)

  Z = 0 0 0 0 0
\end{verbatim}
```

```
Z = zeros(1,5)

Z = 0 0 0 0 0
```

1.15 Text Sizes

`{\tiny ...}`	`{\tiny Black White}`	Black White
`{\scriptsize ...}`	`{\scriptsize Black White}`	Black White
`{\footnotesize ...}`	`{\footnotesize Black White}`	Black White
`{\small ...}`	`{\small Black White}`	Black White
`{\normalsize ...}`	`{\normalsize Black White}`	Black White
`{\large ...}`	`{\large Black White}`	Black White
`{\Large ...}`	`{\Large Black White}`	Black White
`{\LARGE ...}`	`{\LARGE Black White}`	Black White
`{\huge ...}`	`{\huge Black White}`	Black White
`{\Huge ...}`	`{\Huge Black White}`	Black White

1.16 List Structures

1.16.1 Itemize

```
Number representations:

\begin{itemize}
  \item Decimal
  \item Binary
  \item Roman numerals
  \item Fractions
  \item Scientific notation
  \item Knuth's up-arrow
  \item Conway's chained arrow
\end{itemize}
```

Number representations:

- Decimal
- Binary
- Roman numerals
- Fractions
- Scientific notation
- Knuth's up-arrow
- Conway's chained arrow

1.16.2 Enumerate

```
Polygonal numbers:

\begin{enumerate}
  \item Triangular numbers
  \item Square numbers
  \item Pentagonal numbers
  \item Hexagonal numbers
  \item Heptagonal numbers
  \item Octagonal numbers
  \item Nanogonal numbers
  \item Decagonal numbers
  \item Dodecagonal numbers
\end{enumerate}
```

Polygonal numbers:

1. Triangular numbers
2. Square numbers
3. Pentagonal numbers
4. Hexagonal numbers
5. Heptagonal numbers
6. Octagonal numbers
7. Nanogonal numbers
8. Decagonal numbers
9. Dodecagonal numbers

1.16.3 Description

```
Algebraic numbers:

\begin{description}
  \item [Algebraic] number
  \item [Transcendental] number
  \item [Quadratic surd]
  \item [Constructible] number
  \item [Algebraic integer]
\end{description}
```

Algebraic numbers:

Algebraic number

Transcendental number

Quadratic surd

Constructible number

Algebraic integer

1.16.4 Nested Lists

- Only applicable to `itemize` and `enumerate` environments

```
\begin{itemize}

  \item Real numbers
    \begin{itemize}
      \item Rational numbers
      \item Irrational numbers
    \end{itemize}

  \item Complex numbers

\end{itemize}
```

- Real numbers
  - Rational numbers
  - Irrational numbers
- Complex numbers

1.17 Text Alignment Environments

```
\begin{flushleft}
  Viva Miami!
\end{flushleft}

\begin{center}
  Viva Miami!
\end{center}

\begin{flushright}
  Viva Miami!
\end{flushright}
```

Viva Miami!

Viva Miami!

Viva Miami!

1.18 Quotation Marks, Quotation Environments and Footnotes

- English quotation marks: ``mimetic equations'' → “mimetic equations”
- Quotations with the `quote` and `quotation` environments (short, long):

```
\begin{quotation}
  To those who do not know mathematics it is difficult to get across
  a real feeling as to the beauty, the deepest beauty, of nature...
  If you want to learn about nature, to appreciate nature, it is necessary
  to understand the language that she speaks in.%
  \footnote{Richard Feynman, The Character of Physical Law~(1965), Ch.~2}
\end{quotation}
```

> To those who do not know mathematics it is difficult to get across a real feeling as to the beauty, the deepest beauty, of nature... If you want to learn about nature, to appreciate nature, it is necessary to understand the language that she speaks in.[1]

[1] Richard Feynman, The Character of Physical Law (1965), Ch. 2

1.19 Exercises

1. Create a minimal LaTeX document that contains a phrase “Hello, World!”.
2. Start a new LaTeX document of class `article`. Supply a title of your research project with the `\title{}` command.
3. Add your name and the name of your supervisor(s) with the `\author{}` command, e.g. `\author{John Black, Jeremy Grey, Justin White}`.
4. Use the `\maketitle` command to produce a document title.
5. Include a short abstract with the `abstract` environment.
6. Add two sections to the article: one that gives a short motivation for your research (use the `itemize` environment) and another that highlights the main aims of your research (use the `enumerate` environment).
7. Supply labels for each section and refer to one of the sections in the main text.
8. Experiment with different font styles and text sizes.
9. Make use of the `verbatim` environment.
10. Add a phrase in quotation marks.
11. Enable the `url` package with the `\usepackage{url}` command in the document preamble. Include a URL into the main text with the `\url{}` command.
12. Add an appendix section to your document with the `\appendix` and `\section{}` commands.
13. Supply the table of contents for your document with the `\tableofcontents` command.

Chapter 2

Mathematics in LaTeX

2.1 Including Mathematics

- Text, in-line mathematics with `$...$`, `$a^2 + b^2 = c^2$`, $a^2 + b^2 = c^2$
- Displayed, centred mathematics with `\[...\]`, `\[a^2 + b^2 = c^2\]`,

$$a^2 + b^2 = c^2$$

- Advanced mathematics environments with `amsmath` or `mathtools` packages

```
\usepackage{amsmath}
\usepackage{mathtools}
```

- AMS symbols and theorems with `amssymb` and `amsthm` packages

```
\usepackage{amssymb}
\usepackage{amsthm}
```

2.2 Mathematics Commands

- Greek letters
  - `A, \alpha, B, \beta, \Gamma, \gamma, \Pi, \pi, \Sigma, \sigma`
  - A, α, B, β, Γ, γ, Π, π, Σ, σ
  - `u = A \sin (\omega t + \gamma)`, $u = A\sin(\omega t + \gamma)$
- Keyboard symbols `+ - = ! / ( ) [ ] < > '`:
- Command symbols
  - `\forall \in \exists \leq \approx \infty`
  - $\forall \in \exists \leq \approx \infty$
- Superscript (power) `^`, `a^n`, a^n
- Subscript (index) `_`, `a_n`, a_n
- Operators (functions)
  - `\sin, \cos, \tan, \cot, \log, \exp, \lim`
  - `\sin^2 \alpha + \cos^2 \alpha = 1`
  - $\sin^2 \alpha + \cos^2 \alpha = 1$
- Fractions `\frac{1}{256}`, $\frac{1}{256}$
- Simple fractions `1/512`, 1/512

- Powers and indices `^1/_{1024}`, $^1/_{1024}$
- Roots `\sqrt[]{}`, `\sqrt[n]{a}`, $\sqrt[n]{a}$
- Sums `\sum`, `\sum_{n=1}^{256} a_n`, $\sum_{n=1}^{256} a_n$
- Integrals `\int`, `\int_a^b f(x) \, {\mathrm d} x`, $\int_a^b f(x)\,\mathrm{d}x$
- Partial differential `\partial`, `\frac{\partial u}{\partial x}`, $\frac{\partial u}{\partial x}$
- Brackets
  - `( [ \{ | \| \langle \lfloor \lceil`
  - ([{ | ‖ ⟨ ⌊ ⌈
- Automatic sizing of brackets with the `\left ( ... \right )` commands
  - `\left( \frac{x}{a} \right)`, $\left(\frac{x}{a}\right)$
- Matrix environments `matrix`, `pmatrix`, `bmatrix`, `Bmatrix`, `vmatrix`, `Vmatrix`

```
\[
  \begin{matrix}
    a_{1,1} & a_{1,2} & a_{1,3} \\
    a_{2,1} & a_{2,2} & a_{2,3} \\
    a_{3,1} & a_{3,2} & a_{3,3}
  \end{matrix}
\]
```

$$\begin{matrix} a_{1,1} & a_{1,2} & a_{1,3} \\ a_{2,1} & a_{2,2} & a_{2,3} \\ a_{3,1} & a_{3,2} & a_{3,3} \end{matrix}$$

  - Column separator `&`
  - Row separator `\\`
- Text in math mode with the `\text{}` command
  - `1~\text{byte} = 8~\text{bits}`, $1\ \text{byte} = 8\ \text{bits}$
- Accents in math mode
  - `\hat{a}, \bar{b}, \dot{c}, \ddot{d}, \vec{e}`
  - $\hat{a}$, $\bar{b}$, $\dot{c}$, $\ddot{d}$, $\vec{e}$
- Horizontal spacing
  - `\, \: \; \quad`
  - `a \, b  a \: b  a \; b  a \quad b`
  - $a\,b$ $a\:b$ $a\;b$ $a\quad b$
- Dots
  - horizontal `\cdots \ldots \dots`,[1] $\cdots$ $\ldots$ $\dots$
  - vertical `\vdots`, $\vdots$
  - diagonal `\ddots`, $\ddots$

[1] Command `\dots` is only available with the `amsmath` package.

2.3 Defining Theorems

- Theorems package `amsthm`
  - Define a theorem in document preamble with `\newtheorem{theorem}{Theorem}`
  - Use `theorem` environment in the main text

```
\begin{theorem}
  In any right triangle, the area of the square whose side
  is the hypotenuse...
\end{theorem}
```

Theorem 1. *In any right triangle, the area of the square whose side is the hypotenuse...*

  - Use `proof` environment for the proof

```
\begin{proof}[Pythagorean theorem]
  ...
\end{proof}
```

Pythagorean theorem. ... □

  - Define custom environments with the `\newtheorem{}{}` command

```
\newtheorem{lemma}{Lemma}
```

2.4 Equation Environments

- Normal equations with `equation, equation*` environments

```
\begin{equation}
  a_n = a_1 + (n-1)r \quad \text{and} \quad s_n = \frac{n(a_1 + a_n)}{2}
  \label{E:arithmeticProgression}
\end{equation}
```

$$a_n = a_1 + (n-1)r \quad \text{and} \quad s_n = \frac{n(a_1 + a_n)}{2} \tag{2.1}$$

- Multiple aligned equations with `align, align*` environments

```
\begin{align}
  \label{E:MaxwellEqs}
  \frac{\partial B}{\partial t} &= - \nabla \times E - M \\[12pt]
  \frac{\partial D}{\partial t} &= \phantom{-} \nabla \times H - J \notag
\end{align}
```

$$\frac{\partial B}{\partial t} = -\nabla \times E - M \tag{2.2}$$

$$\frac{\partial D}{\partial t} = \nabla \times H - J$$

- Column alignment with `&`, line break with `\\` or `\\[12pt]`

- Suppression of equation numbers with `\notag`
- Long equations spanning multiple lines with `multline, multline*` environments

```
\begin{multline}
  f(x) = f(a) + \frac{x-a}{1!} f'(a) + \frac{(x-a)^2}{2!} f''(a)
              + \frac{(x-a)^3}{3!} f^{(3)}(a) + \frac{(x-a)^4}{4!} f^{(4)}(a)
              + \frac{(x-a)^5}{5!} f^{(5)}(a) + \\[12pt]
              + \frac{(x-a)^6}{6!} f^{(6)}(a) + \frac{(x-a)^7}{7!} f^{(7)}(a)
              + \dots + \frac{(x-a)^n}{n!} f^{(n)}(a) + \dots
  \label{E:TaylorSeries}
\end{multline}
```

$$f(x) = f(a) + \frac{x-a}{1!} f'(a) + \frac{(x-a)^2}{2!} f''(a) + \frac{(x-a)^3}{3!} f^{(3)}(a) + \frac{(x-a)^4}{4!} f^{(4)}(a) + \frac{(x-a)^5}{5!} f^{(5)}(a) + \\ + \frac{(x-a)^6}{6!} f^{(6)}(a) + \frac{(x-a)^7}{7!} f^{(7)}(a) + \cdots + \frac{(x-a)^n}{n!} f^{(n)}(a) + \dots \quad (2.3)$$

- Control the line break with `\\` or `\\[12pt]`
- Comment equations with %
- Label equations with `\label{}` command
- Refer to equations with `\eqref{}` command

2.5 User-Defined Commands

- Create custom commands with `\newcommand{name}{command}`
- Commands must be defined in the document preamble
  - No arguments:
    `\newcommand{\light}{c_0}` `\light` c_0
  - One argument:
    `\newcommand{\veci}[1]{u_{#1}}` `\veci{n}` u_n
  - Two arguments:
    `\newcommand{\mati}[2]{a_{#1, #2}}` `\mati{i}{j}` $a_{i,j}$

2.6 Exercises

1. Start a new article and activate AMS packages `amsmath`, `amssymb`, `amsthm`.

2. Write Pythagorean theorem using in-line math mode `$...$` and command `\sqrt{}`:

$$c = \sqrt{a^2 + b^2}$$

3. Write the freshman's dream equation using in-line math mode and not equals sign:

$$(x+y)^n \neq x^n + y^n$$

4. Write laws of sines, cosines and tangents using displayed math mode `\[...\]`:

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma} = 2R$$

$$a^2 = b^2 + c^2 - 2\,bc\cos\alpha$$

$$\frac{a+b}{a-b} = \frac{\tan\frac{1}{2}(\alpha+\beta)}{\tan\frac{1}{2}(\alpha-\beta)}$$

5. Write formulae of the geometric progression using the `equation` environment:

$$a_n = a_1 q^{n-1} \quad \text{and} \quad s_n = \frac{a_1(q^n-1)}{q-1} \tag{2.4}$$

6. Give example of a sum of a geometric progression using the capital sigma notation:

$$1 + \frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3} + \cdots = \sum_{n=1}^{N} \frac{1}{2^n} = \frac{1}{1-\frac{1}{2}} = 2 \tag{2.5}$$

7. Write the sophomore's dream identities discovered by Johann Bernoulli in 1697 using the `align` environment. State approximate values of the identities up to the 10th digit:

$$\int_0^1 x^{-x}\,\mathrm{d}x = \sum_{n=1}^{\infty} n^{-n} \approx 1.2912859970 \tag{2.6}$$

$$\int_0^1 x^{x}\,\mathrm{d}x = \sum_{n=1}^{\infty} (-1)^{n+1} n^{-n} = -\sum_{n=1}^{\infty} (-n)^{-n} \approx 0.7834305107 \tag{2.7}$$

8. Write the definition of Maclaurin series using the `equation` environment and the capital sigma notation:

$$f(x) = f(0) + \sum_{n=1}^{N} \frac{x^n}{n!} f^{(n)}(0) \tag{2.8}$$

9. Write the definition of Maclaurin series using the `multline` environment. Create a custom command to write a single term of the series and show the first seven terms:

$$f(x) = f(0) + \frac{x}{1!}f'(0) + \frac{x^2}{2!}f''(0) + \frac{x^3}{3!}f^{(3)}(0) + \frac{x^4}{4!}f^{(4)}(0) + \frac{x^5}{5!}f^{(5)}(0) + \\ + \frac{x^6}{6!}f^{(6)}(0) + \frac{x^7}{7!}f^{(7)}(0) + \cdots + \frac{x^n}{n!}f^{(n)}(0) + \ldots \tag{2.9}$$

10. Write a three by four matrix, apply the `pmatrix` or `bmatrix` environments for round or square brackets:

$$M = \begin{pmatrix} m_{1,1} & m_{1,2} & m_{1,3} & m_{1,4} \\ m_{2,1} & m_{2,2} & m_{2,3} & m_{2,4} \\ m_{3,1} & m_{3,2} & m_{3,3} & m_{3,4} \end{pmatrix} \tag{2.10}$$

11. Give definition of the gradient in Cartesian coordinate system, use commands `\nabla` and `\partial`:

$$\nabla U = \frac{\partial U}{\partial x} i + \frac{\partial U}{\partial y} j + \frac{\partial U}{\partial z} k \tag{2.11}$$

2.7 Exercises for Independent Work on Advanced Mathematical Notation

1. **Limit of a multivariable function.** Use `amsmath` package, limit operator `\lim` and command `\substack{}`. Apply the linebreak command `\\` inside of the `\substack{}` in order to switch to the next line. Right directed arrow is typeset with a `\rightarrow` command.

$$A = \lim_{\substack{x \to a \\ y \to b}} f(x, y). \tag{2.12}$$

2. **Derivative of a single variable function.** Use command `\Delta` to typeset a capital Greek letter delta.

$$f'(x) = \lim_{\Delta x \to 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}. \tag{2.13}$$

3. **Number e.** Use command `\infty` to produce an infinity symbol. Automatic sizing of brackets is possible with a pair of commands `\left(` and `\right)`. Italicised text in math-mode is accessible via a `\textit{}` command.

$$\lim_{x \to \infty} \left(1 + \frac{1}{x}\right)^x = e = 2.718282\ldots \quad \textit{(irrational number)}. \tag{2.14}$$

4. **Euler's constant C.** Use operator `\ln{}` to typeset a natural logarithm.

$$\lim_{n \to \infty} \left(1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{n} - \ln n\right) = C = 0.577216\ldots \quad \textit{(Euler's constant)}. \tag{2.15}$$

5. **Duality map $F(x_0)$.** Use commands `\{`, `\|`, `\la` and `\ra` as well as the manual sizing command `\Big` to typeset various brackets. A star might be produced with a `\star` command [14].

$$F(x_0) = \left\{ f_0 \in E^\star; \quad \|f_0\| = \|x_0\| \text{ and } \langle f_0, x_0 \rangle = \|x_0\|^2 \right\}. \tag{2.16}$$

6. **Gamma function.** Use command `\Gamma` to write a capital Greek letter gamma. Integral symbol is produced with the `\int` command. Apply `cases` environment of the `amsmath` package to create a definition of a piecewise function. Syntax inside of the `cases` environment is the same as in the `tabular` environment (symbols `&` and `\\`). Text in math-mode is written inside of a `\text{}` command.

$$\Gamma(x) \begin{cases} = \displaystyle\int_0^\infty e^{-t} t^{x-1} \, \mathrm{d}t \quad \textit{(Euler's integral)} & \text{only if} \quad x > 0, \\ = \displaystyle\lim_{n \to \infty} \frac{n!\, n^{x-1}}{x(x+1)(x+2)\ldots(x+n-1)} & \text{for any} \quad x. \end{cases} \tag{2.17}$$

7. **Newton's binom.** Use `multline` environment of the `amsmath` package and the linebreak command \\ to split the formula at the appropriate place.

$$(a+b)^n = a^n + na^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \cdots + \\ + \frac{n(n-1)\ldots(n-m+1)}{m!}a^{n-m}b^m + \cdots + nab^{n-1} + b^n. \quad (2.18)$$

8. **Bernoulli's numbers.** Plus/minus and minus/plus symbols are produced with the `\pm` and `\mp` commands in math-mode. Greek letter pi is written with a `\pi` command.

$$1 - \frac{1}{2^{2k}} + \frac{1}{3^{2k}} - \frac{1}{4^{2k}} + \cdots \pm \frac{1}{n^{2k}} \mp \cdots = \frac{\pi^{2k}(2^{2k-1}-1)}{(2k)!}B_k. \quad (2.19)$$

9. **Euler's numbers**

$$1 - \frac{1}{3^{2k+1}} + \frac{1}{5^{2k+1}} - \frac{1}{7^{2k+1}} + \cdots \pm \frac{1}{(2n-1)^{2k+1}} \mp \cdots = \frac{\pi^{2k+1}}{2^{2k+2}(2k)!}E_k. \quad (2.20)$$

10. **Stokes' formula.** Define two custom commands: one without arguments to typeset a differential over a given variable ($\mathrm{d}x$) and another with two arguments to typeset a fraction of partial differentials $\left(\frac{\partial Q}{\partial x}\right)$. Hamiltonian (nabla operator) is written with a `\nabla` command and a cross product—with a `\times` command. Closed contour integral is given with an `\oint` command of the `amsmath` package and bold font face in math-mode is set with a `\mathbf{}` command. Use the `align` environment to write Stokes' formula in Cartesian coordinates and in vector form.

$$\int_K P\,\mathrm{d}x + Q\,\mathrm{d}y + R\,\mathrm{d}z = \int_S \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right)\mathrm{d}x\,\mathrm{d}y + \left(\frac{\partial R}{\partial y} - \frac{\partial Q}{\partial z}\right)\mathrm{d}y\,\mathrm{d}z + \left(\frac{\partial P}{\partial z} - \frac{\partial R}{\partial x}\right)\mathrm{d}z\,\mathrm{d}x, \quad (2.21)$$

$$\int_\Sigma \nabla \times \mathbf{V}\,\mathrm{d}S = \oint_C \mathbf{V}\,\mathrm{d}\mathbf{r}. \quad (2.22)$$

11. **Curl theorem applied to Maxwell's equations.** Triple integral is written with `\iiint` command and double closed surface integral with—`\oiint`. Matrices in square brackes are typeset with `bmatrix` environment, while commands `\hat{}` and `\vec{}` produce the accents required.

$$\iiint_V \nabla \times \begin{bmatrix} \vec{E} \\ \vec{H} \end{bmatrix} \mathrm{d}V = \oiint_S \begin{bmatrix} \hat{n} \times \vec{H} \\ \hat{n} \times \vec{E} \end{bmatrix} \mathrm{d}S. \quad (2.23)$$

12. **Green's formula**

$$\int_K P\,\mathrm{d}x + Q\,\mathrm{d}y = \iint_S \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right)\mathrm{d}x\,\mathrm{d}y. \quad (2.24)$$

13. **Green's theorems**

$$\int\limits_{\Sigma} U_1 \nabla U_2 \, \mathrm{d}S = \int\limits_{v} (U_1 \Delta U_2 + \nabla U_1 \nabla U_2) \, \mathrm{d}v, \tag{2.25}$$

$$\int\limits_{\Sigma} (U_1 \nabla U_2 - U_2 \nabla U_1) \, \mathrm{d}S = \int\limits_{v} (U_1 \Delta U_2 - U_2 \Delta U_1) \, \mathrm{d}v, \tag{2.26}$$

$$\int\limits_{\Sigma} \nabla U \, \mathrm{d}S = \int\limits_{v} \Delta U \, \mathrm{d}v \quad (\textit{for} \quad U_1 = 1). \tag{2.27}$$

14. **Ostrogradsky–Gauss' formula**

$$\iiint\limits_{V} \left(\frac{\partial P}{\partial x} + \frac{\partial Q}{\partial y} + \frac{\partial R}{\partial z} \right) \mathrm{d}V = \iint\limits_{S} P \, \mathrm{d}y \, \mathrm{d}z + Q \, \mathrm{d}z \, \mathrm{d}x + R \, \mathrm{d}x \, \mathrm{d}y, \tag{2.28}$$

$$\int\limits_{v} \nabla \mathbf{V} \, \mathrm{d}v = \oint\limits_{\Sigma} \mathbf{V} \, \mathrm{d}S. \tag{2.29}$$

15. **Fresnel integrals.** Apply a custom command without arguments to typeset a differential over a given variable dx. Use commands `\left(` and `\right)` to create a pair of round brackets inside of the sine and cosine operators. Equivalents symbol ≡ is accessible via an `\equiv` command.

$$C(u) + iS(u) = \int\limits_{0}^{u} e^{i\pi x^2/2} \, \mathrm{d}x = \int\limits_{0}^{u} \cos\left(\frac{1}{2} \pi x^2 \right) \mathrm{d}x + i \int\limits_{0}^{u} \sin\left(\frac{1}{2} \pi x^2 \right) \mathrm{d}x, \tag{2.30}$$

where

$$C(u) \equiv \int\limits_{0}^{u} \cos\left(\frac{1}{2} \pi x^2 \right) \mathrm{d}x, \quad S(u) \equiv \int\limits_{0}^{u} \sin\left(\frac{1}{2} \pi x^2 \right) \mathrm{d}x. \tag{2.31}$$

16. **Signum function ★** Use `amsmath` package and `\DeclareMathOperator{\sgn}{sgn}` command to define a signum operator `sgn`. Command `\phantom{}` is necessary to insert "phantom" spaces in front of numbers 0 and 1.

$$y = \operatorname{sgn} x, \quad y = \begin{cases} -1 & \text{if} \quad x < 0, \\ 0 & \text{if} \quad x = 0, \\ 1 & \text{if} \quad x > 0. \end{cases} \tag{2.32}$$

17. **Independence of multivariable functions ★** $u_1 = f_1(x_1, x_2, \ldots, x_n), \ldots, u_n = f_n(x_1, x_2, \ldots, x_n)$ Use `vmatrix` environment of the `amsmath` package to create a matrix with vertical bars. Partial differential is written with the `\partial` command. Equivalence and not equals symbols are produced with the commands `\equiv` and `\neq`. Define a custom command with two arguments to typeset a generic element of the matrix.

$$\begin{vmatrix} \dfrac{\partial f_1}{\partial x_1} & \dfrac{\partial f_1}{\partial x_2} & \cdots & \dfrac{\partial f_1}{\partial x_n} \\ \dfrac{\partial f_2}{\partial x_1} & \dfrac{\partial f_2}{\partial x_2} & \cdots & \dfrac{\partial f_2}{\partial x_n} \\ \cdots & \cdots & \cdots & \cdots \\ \dfrac{\partial f_n}{\partial x_1} & \dfrac{\partial f_n}{\partial x_2} & \cdots & \dfrac{\partial f_n}{\partial x_n} \end{vmatrix} \equiv \frac{D(f_1, f_2, \ldots, f_n)}{D(x_1, x_2, \ldots, x_n)} \neq 0. \tag{2.33}$$

18. **General expression of a third order derivative via differentials ★** Use commands `\left[` and `\right]` to create a pair of square brackets, and environment `vmatrix*` from the package `mathtools` to typeset matrix expressions. Specify an optional column alignment parameter `[l]` of the `vmatrix*` environment as `\begin{vmatrix*}[l]`. Define a custom command with one argument `\dn{}` to typeset a differential of a given order. Apply a negative spacing command `\!` to compress horizontal space in between the symbols d^3 and x to produce d^3x.

$$y''' = \left[\mathrm{d}x \begin{vmatrix} \mathrm{d}x & \mathrm{d}y \\ \mathrm{d}^3x & \mathrm{d}^3y \end{vmatrix} - 3\,\mathrm{d}^2x \begin{vmatrix} \mathrm{d}x & \mathrm{d}y \\ \mathrm{d}^2x & \mathrm{d}^2y \end{vmatrix} \right] : \mathrm{d}x^5. \tag{2.34}$$

Chapter 3

Graphics and Tables in LaTeX

3.1 Graphics

3.1.1 Introduction

- Use package `graphicx` to enable graphics support
- Create graphic files in vector format (scalable)
- Use external programs to create graphics

  - Adobe Illustrator
  - CorelDRAW
  - FreeHand
  - TikZ/PGF
  - Xfig
  - Ipe
  - Inkscape
  - Dia
  - Adobe Photoshop
  - GIMP
  - ImageMagick (convert, mogrify)
  - Gnuplot
  - R
  - Generic Mapping Tools (GMT)
  - Gnumeric
  - Matplotlib

- DVI output with `latex` → include graphic files in EPS format
- PDF output with `pdflatex` → include graphic files in PDF, JPG, PNG
- Include graphics with the `\includegraphics[opts]{file_name}` command
- Common options include `width`, `height`, `scale`, `angle`, e.g.

  ```
  width=0.5\textwidth, height=0.25\textheight, scale=0.75, angle=90
  ```

- Command `\graphicspath{}` to direct LaTeX in search for graphic files

  ```
  \graphicspath{ {pic/}{plot/}{diag/} }
  ```

- Alternatively: `\includegraphics{path/file_name}`
- No need to specify the file extension: LaTeX will automatically select the right file (EPS or PDF)

3.1.2 Measurement Units

pt	≈ 0.3515 mm
mm	mm
cm	cm
in	inch
ex	height of “x”
em	width of “M”

3.1.3 Length Specifiers

```
\linewidth
\columnwidth
\textwidth
\textheight
\paperwidth
\paperheigth
\parindent
\parskip
```

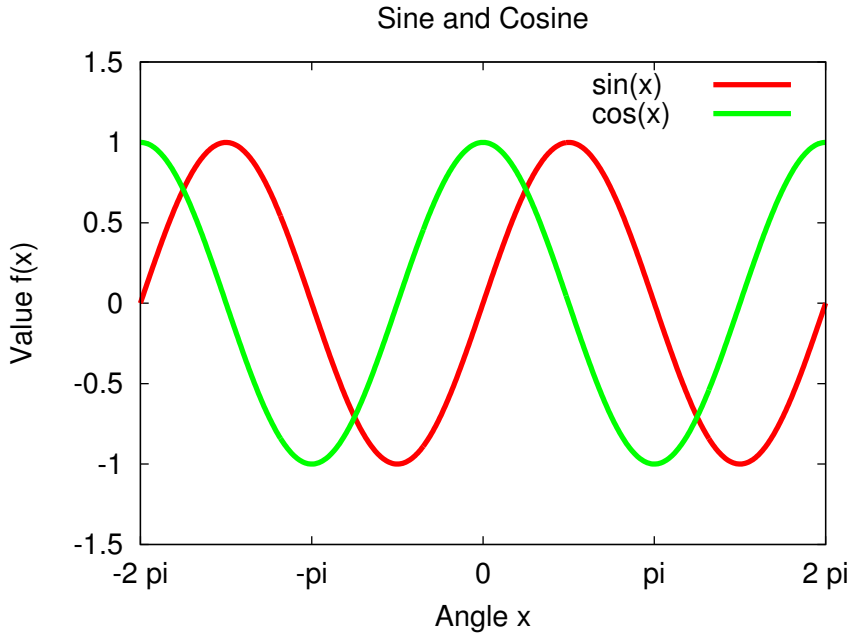
3.1.4 Custom Length Commands

- Define a new length parameter: `\newlength{parameter}`
- Set length of a new parameter: `\setlength{parameter}{length}`
- Change length of a parameter: `\addtolength{parameter}{length}`

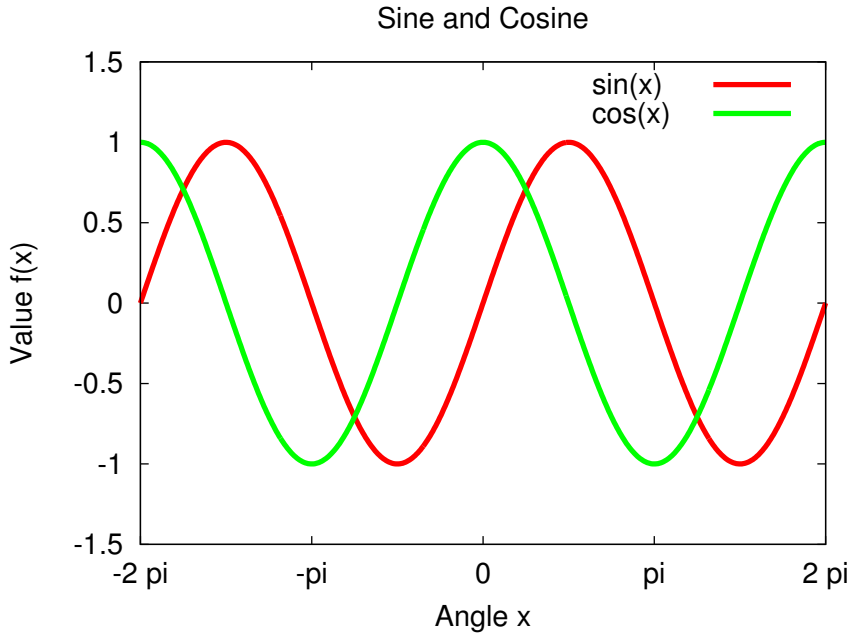
```
\newlength{lh}    % line height
\setlength{12pt}  % set length to 12pt
...
\vspace{2\lh}     % vertical spacing of 2 line heights (main text)
...
\\[2\lh]          % vertical spacing of 2 line heights (math mode, tables)
```

3.1.5 Examples of Graphics Inclusion

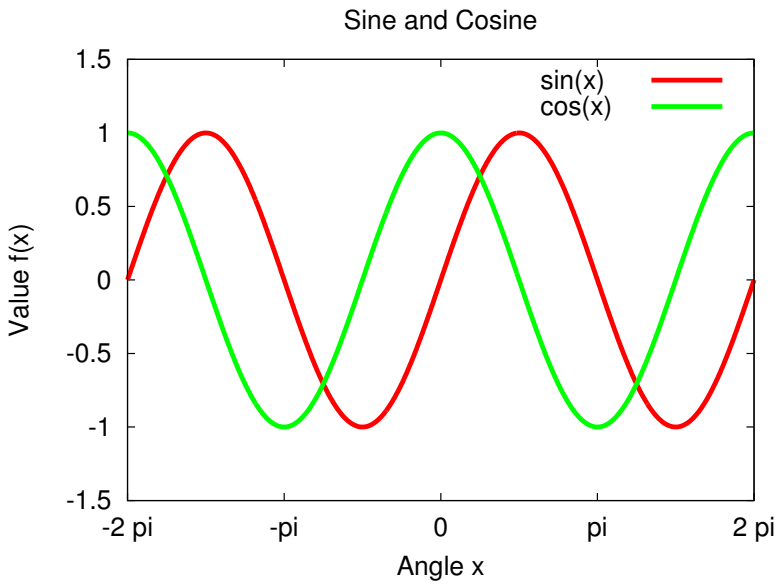
```
\includegraphics[width=12.5cm]{plot/sin-cos}
```



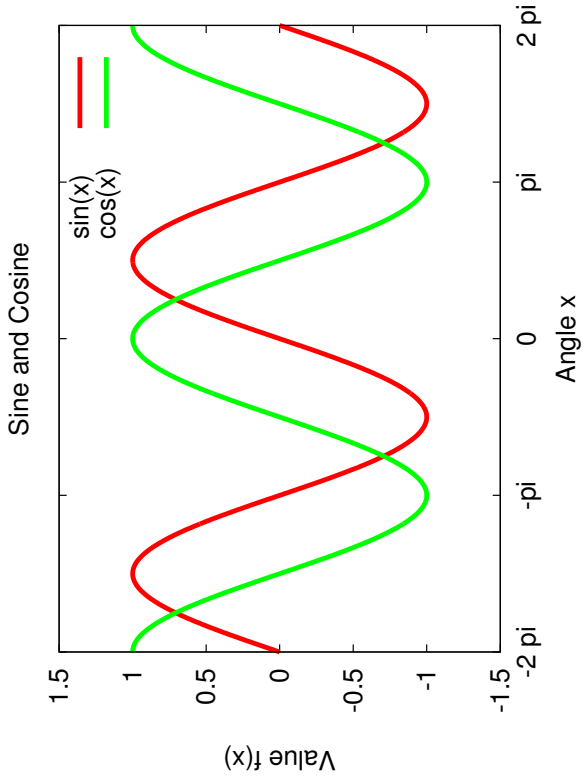

```
\includegraphics[height=8.75cm]{plot/sin-cos}
```



```
\includegraphics[scale=0.9]{plot/sin-cos}
```




```
\includegraphics[scale=0.9,angle=90]{plot/sin-cos}
```



3.1.6 Figures

- Float: container, encloses content, holds it on one page
- Floats: Figures, Tables, Algorithms, Listings, ...
- Use `figure` environment

```
\begin{figure}[htbp]
  \centering
  \includegraphics[scale=0.9]{plot/sin-cos}
  \caption{Plots of $\sin{(x)}$ and $\cos{(x)}$}
  \label{F:sin-cos}
\end{figure}
```

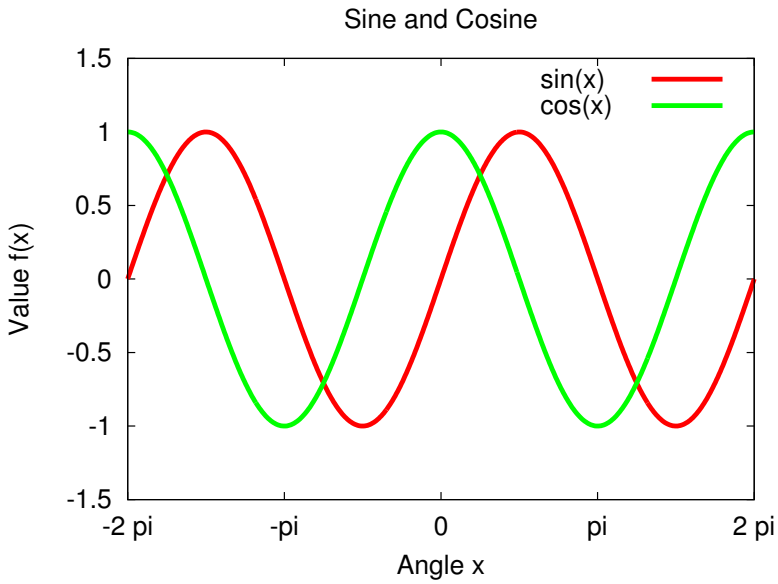


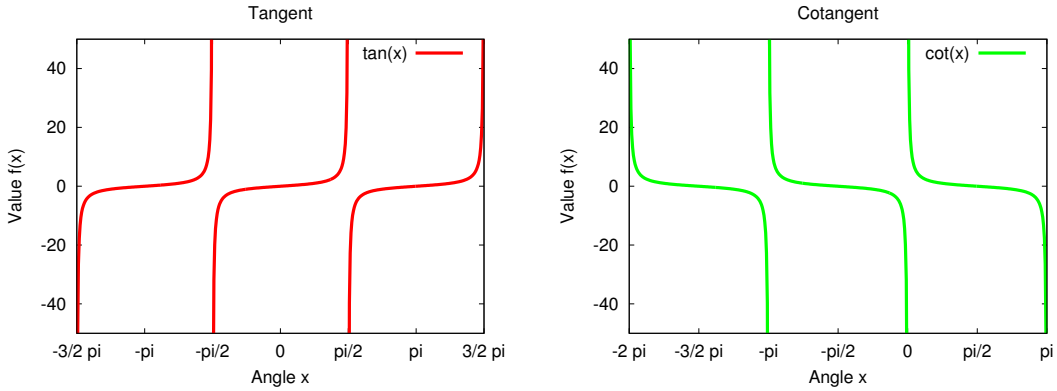
Figure 3.1: Plots of $\sin(x)$ and $\cos(x)$

- Supply an image with a caption and label for future reference
- Positioning commands: h—here, t—top, b—bottom, p—page
- Enforce float position with `h!` if necessary
- Use `\listoffigures` command to show the list of figures

3.1.7 Subfigures

- Use `subfigure` environment for multiple figures as part of one float
- Enable packages: `graphicx`, `caption`, `subcaption`

```
\begin{figure}[h]
  \begin{subfigure}[b]{0.5\textwidth}
    \centering
    \includegraphics[scale=0.6]{plot/tan}
    \caption{Plot of $\tan{(x)}$}
    \label{F:tan}
  \end{subfigure}
  %
  \begin{subfigure}[b]{0.5\textwidth}
    \centering
    \includegraphics[scale=0.6]{plot/cot}
    \caption{Plot of $\cot{(x)}$}
    \label{F:cot}
  \end{subfigure}
  %
  \caption{Plots of $\tan{(x)}$ and $\cot{(x)}$}
  \label{F:tan-cot}
\end{figure}
```



(a) Plot of $\tan(x)$

(b) Plot of $\cot(x)$

Figure 3.2: Plots of $\tan(x)$ and $\cot(x)$ [1]

3.2 Tables

3.2.1 Basic Tables

- Basic `tabular` environment

```
\begin{tabular}{ccc}
1   &   2   &   3   \\
4   &   5   &   6   \\
7   &   8   &   9   \\
*   &   0   &   \#  \\
\end{tabular}
```

1 2 3
4 5 6
7 8 9
* 0 #

- Cell alignment c—centre, l—left, r—right
- Number of alignment commands = number of columns `{ccc}`
- Column separator `&`
- Row separator `\\`

3.2.2 Tables with Vertical Bars

- Specify vertical bars with the "|" symbols in the alignment, e.g. `{|r|l|r|l|l|}`

```
\begin{tabular}{|r|l|r|r|}
World Rank & Institution                                & Total Score & Score on Alumni \\
         1 & Harvard University                        & 100.0       & 100.0           \\
         2 & Stanford University                       &  72.6       &  41.2           \\
         3 & Massachusetts Institute of Technology (MIT) &  72.0       &  72.8           \\
         4 & University of California, Berkeley        &  71.9       &  68.3           \\
         5 & University of Cambridge                   &  70.0       &  87.1           \\
         6 & California Institute of Technology        &  64.7       &  52.6           \\
         7 & Princeton University                      &  61.2       &  56.7           \\
         8 & Columbia University                       &  60.4       &  69.6           \\
         9 & University of Chicago                     &  57.5       &  65.0           \\
        10 & University of Oxford                      &  56.4       &  55.5           \\
  $\vdots$ & $\vdots$                                  & $\vdots$    & $\vdots$        \\
        38 & The University of Manchester              &  34.8       &  21.2           \\
\end{tabular}
```

World Rank	Institution	Total Score	Score on Alumni
1	Harvard University	100.0	100.0
2	Stanford University	72.6	41.2
3	Massachusetts Institute of Technology (MIT)	72.0	72.8
4	University of California, Berkeley	71.9	68.3
5	University of Cambridge	70.0	87.1
6	California Institute of Technology	64.7	52.6
7	Princeton University	61.2	56.7
8	Columbia University	60.4	69.6
9	University of Chicago	57.5	65.0
10	University of Oxford	56.4	55.5
⋮	⋮	⋮	⋮
38	The University of Manchester	34.8	21.2

3.2.3 Tables with Horizontal Bars

- Specify horizontal bars with the `\hline` commands

```
\begin{tabular}{|l|r|r|r|}
  \hline
  UK Census 2001    & Manchester  & Greater Manchester  & England \\
  \hline
  Total population  & 398,819     & 2,547,700           & 49,138,831 \\
  Foreign born      & 15.0\%      &  7.2\%              &  9.2\% \\
  White             & 81.0\%      & 91.0\%              & 91.0\% \\
  Asian             &  9.1\%      &  5.7\%              &  4.6\% \\
  Black             &  4.5\%      &  1.2\%              &  2.3\% \\
  Over 75 years old &  6.4\%      &  7.0\%              &  7.5\% \\
  Christian         & 62.4\%      & 74.0\%              & 71.8\% \\
  Muslim            &  9.1\%      &  5.0\%              &  3.1\% \\
  \hline
\end{tabular}
```

UK Census 2001	Manchester	Greater Manchester	England
Total population	398,819	2,547,700	49,138,831
Foreign born	15.0%	7.2%	9.2%
White	81.0%	91.0%	91.0%
Asian	9.1%	5.7%	4.6%
Black	4.5%	1.2%	2.3%
Over 75 years old	6.4%	7.0%	7.5%
Christian	62.4%	74.0%	71.8%
Muslim	9.1%	5.0%	3.1%

3.2.4 Rows Spanning Multiple Columns

- Rows over multiple columns (headings, titles):

  `\multicolumn{span}{layout}{content}`, e.g. `\multicolumn{5}{c}{Heading}`

```
\begin{tabular}{|r|l|r|r|r|}
  \hline
  \multicolumn{5}{|c|}{World population (millions)} \\
  \hline
 Rank & Most populous countries &  1990 &  2008 &  2025 \\
  \hline
    1 & China                   & 1,141 & 1,333 & 1,458 \\
    2 & India                   &   849 & 1,140 & 1,398 \\
    3 & United States           &   250 &   304 &   352 \\
    4 & Indonesia               &   178 &   228 &   273 \\
    5 & Brazil                  &   150 &   192 &   223 \\
    6 & Pakistan                &   108 &   166 &   226 \\
    7 & Bangladesh              &   116 &   160 &   198 \\
    8 & Nigeria                 &    94 &   151 &   208 \\
    9 & Russia                  &   148 &   142 &   137 \\
   10 & Japan                   &   124 &   128 &   126 \\
  \hline
\end{tabular}
```

World population (millions)				
Rank	Most populous countries	1990	2008	2025
1	China	1,141	1,333	1,458
2	India	849	1,140	1,398
3	United States	250	304	352
4	Indonesia	178	228	273
5	Brazil	150	192	223
6	Pakistan	108	166	226
7	Bangladesh	116	160	198
8	Nigeria	94	151	208
9	Russia	148	142	137
10	Japan	124	128	126

3.2.5 Professional Tables

- Professional tables: `booktabs` package
- Horizontal bars only: commands `\toprule`, `\midrule`, `\bottomrule`
- Column headings in bold font face with the `{\bf ...}` command

```
\begin{tabular}{lrr}
  \toprule
  {\bf Continent} & {\bf Density} & {\bf Population} \\
  \midrule
    Asia          & 86.7          & 4,140,336,501    \\
    Africa        & 32.7          &   994,527,534    \\
    Europe        & 70            &   738,523,843    \\
    North America & 22.9          &   528,720,588    \\
    South America & 21.4          &   385,742,554    \\
    Oceania       &  4.25         &    36,102,071    \\
    Antarctica    &  0            &         4,490    \\
  \bottomrule
\end{tabular}
```

Continent	**Density**	**Population**
Asia	86.7	4,140,336,501
Africa	32.7	994,527,534
Europe	70	738,523,843
North America	22.9	528,720,588
South America	21.4	385,742,554
Oceania	4.25	36,102,071
Antarctica	0	4,490

3.2.6 Table Floating Environment

- Table with a floating environment `table`
- Basic structure

```
\begin{table}[htbp]
\centering
  \begin{tabular}{lll}
    ...
  \end{tabular}
\caption{...}
\label{T: ...}
\end{table}
```

```
\begin{table}[h]
  \centering
  \begin{tabular}{lrr}
  \toprule
  {\bf Continent} & {\bf Density} & {\bf Population} \\
  \midrule
    Asia          & 86.7          & 4,140,336,501    \\
    Africa        & 32.7          &   994,527,534    \\
    Europe        & 70            &   738,523,843    \\
    North America & 22.9          &   528,720,588    \\
    South America & 21.4          &   385,742,554    \\
    Oceania       &  4.25         &    36,102,071    \\
    Antarctica    &  0            &         4,490    \\
  \bottomrule
  \end{tabular}
  \caption{Population by continents~\cite{WorldBank08}}
  \label{T:populationData}
\end{table}
```

Continent	**Density**	**Population**
Asia	86.7	4,140,336,501
Africa	32.7	994,527,534
Europe	70	738,523,843
North America	22.9	528,720,588
South America	21.4	385,742,554
Oceania	4.25	36,102,071
Antarctica	0	4,490

Table 3.1: Population by continents [11]

3.3 Exercises

3.3.1 Graphics

1. Create an empty document.
2. Include the graphics file provided using a single `\includegraphics[]{}` command.
3. Set the graphics size by using the `width`, `height`, `scale` options.
4. Rotate graphics with an `angle` option.
5. Introduce a floating environment `figure`, set figure's caption and label.
6. Refer to a figure in the text.
7. Create a figure consisting of two horizontally placed subfigures.

3.3.2 Tables

8. Recreate one of the tables provided in the lecture, use the `tabular` environment.
9. Specify the column alignment.
10. Use horizontal and vertical bars.
11. Make one of the rows to span two or more columns of the table.
12. Redesign the table by using the `booktabs` package.
13. Convert the table into a float by using the `table` environment.
14. Specify table caption and label.
15. Refer to the table in the text.

Chapter 4

Bibliography Management

- Bibliography inclusion: embedded system and BibTeX

4.1 Embedded System

```
\begin{thebibliography}{9}  % label width

  \bibitem{Courant67}       % citation key
    Richard~Courant, Kurt~Friedrichs, Hans~Lewy
    On the Partial Difference Equations of Mathematical Physics
    {\em IBM Journal, pp.~215--234},
    March, 1967

  \bibitem{Berenger05}      % citation key
    Jean-Pierre~B\'{e}renger
    A FDTD Subgridding Based on Huygens Surfaces
    {\em IEEE AP-S International Symposium},
    2005, Washington D.C., USA

  \bibitem{Taflove05}       % citation key
    Allen~Taflove, Susan C.~Hagness
    {\em Computational Electrodynamics:\\
    The Finite-Difference Time-Domain Method, 3rd Edition}.
    Artech House, 2005

\end{thebibliography}
...
\end{document}
```

- Use embedded system for documents with small amount of references (presentations, posters)

4.2 Citing References

- Cite your references with the `\cite[opts]{key}` command

```
Courant et al.~\cite{Courant67} have defined...

Berenger~\cite{Berenger05} provides a detailed explanation...

Taflove and Hagness~\cite[Ch.~3, pp.~67--108]{Taflove05} introduce...
```

- Multiple citations

```
See~\cite{Courant67,Berenger05,Taflove05} for theoretical background...
```

- Citation keys are case-sensitive
- No space is allowed between the citation keys
- `\nocite{Courant67}`: citation will appear only in the bibliography, but not in the main text
- `\nocite{*}`: all citations will appear in the bibliography, but not in the main text (testing)

4.3 BibTeX

- BibTeX: references → plain text file with the extension `*.bib`
- BibTeX: database entry

```
@ARTICLE{Costen09,
  title   = {Comparison of {FDTD} Hard Source With {FDTD}
             Soft Source and Accuracy Assessment in {D}ebye Media},
  author  = {Costen, F. and B\'{e}renger, J.-P. and Brown, A.K.},
  journal = {{IEEE} {T}ransactions on {A}ntennas and {P}ropagation},
  volume  = {57},
  number  = {7},
  pages   = {2014--2022},
  year    = {2009}
}
```

- Generic form:

```
@ENTRY_TYPE{citation_key,
  title   = {...},
  author  = {...},  % separate multiple authors with ‘‘and’’
  journal = {...},  % use ‘‘{}’’ to preserve capital letters
  volume  = {...},
  number  = {...},
  pages   = {...},
  year    = {...}
}
```

4.3.1 Standard BibTeX entries

- Published article (journal, magazine)

```
@ARTICLE{,
  author  = {},  % required
  title   = {},
  journal = {},
  year    = {},
  volume  = {},  % optional
  number  = {},
  pages   = {},
  month   = {},
  note    = {}
}
```

- Article in conference proceedings

```
@INPROCEEDINGS{,
  title        = {},  % required
  author       = {},
  booktitle    = {},
  year         = {},
  editor       = {},  % optional
  volume       = {},
  number       = {},
  series       = {},
  pages        = {},
  address      = {},
  month        = {},
  organization = {},
  publisher    = {},
  note         = {}
}
```

- Conference proceedings

```
@PROCEEDINGS{,
  title        = {},  % required
  year         = {},
  editor       = {},  % optional
  volume       = {},
  number       = {},
  series       = {},
  address      = {},
  month        = {},
  organization = {},
  publisher    = {},
  note         = {}
}
```

- Published book

```
@BOOK{,
  title     = {},  % required
  publisher = {},
  year      = {},
  author    = {},  % alternative: editor
  volume    = {},  % optional
  number    = {},
  series    = {},
  address   = {},
  edition   = {},
  month     = {},
  note      = {}
}
```

- Book section w/o an independent title

```
@INBOOK{,
  title     = {},  % required
  chapter   = {},
  publisher = {},
  year      = {},
  author    = {},  % alternative: editor
  volume    = {},  % optional
  number    = {},
  series    = {},
  type      = {},
  address   = {},
  edition   = {},
  month     = {},
  pages     = {},
  note      = {}
}
```

- Book section with an independent title

```
@INCOLLECTION{,
  author    = {},  % required
  title     = {},
  booktitle = {},
  publisher = {},
  year      = {},
  pages     = {},  % optional
  editor    = {},
  volume    = {},
  number    = {},
  series    = {},
  type      = {},
  chapter   = {},
  address   = {},
  edition   = {},
  month     = {},
  note      = {}
}
```

- PhD thesis

```
@PHDTHESIS{,
  author  = {},  % required
  title   = {},
  school  = {},
  year    = {},
  type    = {},  % optional
  address = {},
  month   = {},
  note    = {}
}
```

- Master's thesis

```
@MASTERSTHESIS{,
  author  = {},  % required
  title   = {},
  school  = {},
  year    = {},
  type    = {},  % optional
  address = {},
  month   = {},
  note    = {}
}
```

- Technical manual

```
@MANUAL{,
  title        = {},  % required
  author       = {},  % optional
  organization = {},
  address      = {},
  edition      = {},
  month        = {},
  year         = {},
  note         = {}
}
```

- Technical report from a named institution

```
@TECHREPORT{,
  author      = {},  % required
  title       = {},
  institution = {},
  year        = {},
  type        = {},  % optional
  number      = {},
  address     = {},
  month       = {},
  note        = {}
}
```

- Bound document w/o publisher/sponsor

```
@BOOKLET{,
  title        = {},  % required
  author       = {},  % optional
  howpublished = {},
  address      = {},
  month        = {},
  year         = {},
  note         = {}
}
```

- Unpublished work

```
@UNPUBLISHED{,
  author = {},  % required
  title  = {},
  note   = {},
  month  = {},  % optional
  year   = {}
}
```

- Miscellaneous (other kinds of publications)

```
@MISC{,
  author       = {}, % optional
  title        = {},
  howpublished = {},
  month        = {},
  year         = {},
  note         = {}
}
```

4.3.2 Non-Standard BibTeX Entries

- Supported by the IEEE Transactions BibTeX style file `IEEEtran` [13]
- Website, manual in electronic form

```
@ELECTRONIC{,
  author        = {},
  title         = {},
  organization  = {},
  address       = {},
  howpublished  = {},  % {file, mailing list} name, RFC no., book series
  url           = {},
  month         = {},
  year          = {},
  key           = {}   % sorting key
}
```

- Patent and patent request

```
@PATENT{,
  author      = {},
  assignee    = {},
  address     = {},
  title       = {},
  language    = {},
  nationality = {},
  type        = {},  % patent request
  number      = {},
  dayfiled    = {},
  monthfiled  = {},
  yearfiled   = {},
  day         = {},
  month       = {},
  year        = {}
}
```

- Standard

```
@STANDARD{,
  title        = {},
  organization = {},  % alternative: institution
  address      = {},
  number       = {},
  type         = {},
  revision     = {},  % revision no.
  month        = {},
  year         = {}
}
```

- Periodical publication

```
@PERIODICAL{,
  title  = {},
  volume = {},
  month  = {},
  year   = {},
  key    = {}  % sorting key
}
```

4.3.3 Example BibTeX File

- Text file with the extension `*.bib` and BibTeX entries:

```
@ARTICLE{Courant67,
  author  = {Richard Courant and Kurt Friedrichs and Hans Lewy},
  title   = {On the Partial Difference Equations of Mathematical Physics},
  journal = {IBM Journal},
  pages   = {215--234},
  month   = {March},
  year    = {1967}
}

@INPROCEEDINGS{Berenger05,
  author    = {Jean-Pierre B\'{e}renger},
  title     = {A {FDTD} Subgridding Based on {H}uygens Surfaces},
  booktitle = {IEEE AP-S International Symposium},
  year      = {2005},
  address   = {Washington D.C., USA}
}

@BOOK{Taflove05,
  author    = {Allen Taflove and Susan C. Hagness},
  title     = {Computational Electrodynamics:
               The Finite-Difference Time-Domain Method},
  publisher = {Artech House},
  edition   = {third},
  year      = {2005}
}
```

4.3.4 URLs in BibTeX

- Including URLs into BibTeX references:
  - Use the `url` package
  - Place the URL into the `note` or `howpublished` keyword

```
note = { \url{http://www.manchester.ac.uk} }
```

- BibTeX entry with a website reference:

```
@MISC{Manchester12,
  title        = {The University of Manchester, {M}ain website},
  howpublished = { \url{http://www.manchester.ac.uk} },
  month        = {May},
  year         = {2012},
  note         = {Accessed: May~24, 2012}
}
```

- IEEEtran bibliography style: `url` field for each entry

```
@PHDTHESIS{Abalenkovs11,
  author  = {Maksims Aba\c{l}enkovs},
  title   = {{H}uygens {S}ubgridding for
             the {F}requency-{D}ependent--{F}inite-{D}ifference
             {T}ime-{D}omain {M}ethod},
  school  = {The University of Manchester,
             School of Electrical and Electronic Engineering},
  year    = {2011},
  address = {Sackville Street Building, Manchester, M60~1QD, United Kingdom},
  month   =  nov # { 24,},
  url     = {https://www.escholar.manchester.ac.uk/
             item/?pid=uk-ac-man-scw:137344}
}
```

4.3.5 Including BibTeX files into LaTeX documents

- BibTeX: commands to add at the end of document

```
\bibliographystyle{plain}       % bibliography appearance
\bibliography{cem,subgridding}  % bibliography files
...
\end{document}
```

- Change in the compilation process:

```
(pdf)latex      article.tex
     bibtex     article
(pdf)latex      article.tex
(pdf)latex      article.tex
```

4.3.6 Housekeeping Issues

- Finding and managing references with Google Scholar and JabRef
- Importance of keeping different BibTeX files for different topics
- Internal naming of references and PDF files:

  `SurnameXYz` → Berenger06a, Berenger06b, Berenger11

4.3.7 Customisation of Citation Appearance

- Use the `cite` package for citation sorting and compression: [1,7,5,6,2] → [1,2,5–7].
- Use the `natbib` package for advanced customisation of citation appearance
- Harvard citation style:
  - Include `natbib` package
  - Set bibliography style to `plainnat` with `\bibliographystyle{plainnat}`
  - Use the `\citep{}` or `citep*{}` command instead of `\cite{}`

    `\citep{Courant67}` → (Courant et al., 1967)

    `\citep*{Courant67}` → (Courant, Friedrichs, and Lewy, 1967)

4.3.8 Exporting EndNote Citations into BibTeX

- EndNote: built-in output style “BibTeX Output”
- In EndNote menu: File → Output Styles → Open Style Manager
- Select “BibTeX Output” out of available output styles
- In EndNote menu: File → Export
- EndNote `*.enl` file converted to BibTeX `*.bib` file

4.4 Exercises

1. Create new text file and save it in BibTeX format by changing the file extension to `*.bib`.
2. Find the most influential book in your research area using the library catalogue.
3. Manually add the book entry into your BibTeX file.

   if (($author$ == you) & ($publications \geq 3$)) **then**
   create bibliography file with your own scientific contributions
   else
   find find three most influential articles in your research area using Google Scholar
   copy, paste, edit article entries in your bibliography file
   end if

4. Add an entry for your own Master's or PhD thesis.
5. Insert your bibliography file into your LaTeX document with the `\bibliography{}` command.
6. Set the bibliography style with the `\bibliographystyle{}` command.
7. Insert multiple citations of the documents in your bibliography list into your article, use the `\cite{}` command.
8. Specify a book chapter and page numbers using the optional arguments of the `\cite[]{}` command.
9. Compile your document and observe the appearance of references in the text and the appearance of bibliography at the end of the document.
10. Experiment with different bibliography styles `plain`, `abbrv`, `alpha`, `IEEEtran`, recompile the document each time and observe the changes.
11. Create an entry for a website in your bibliography file.
12. Add more entries of different types to your bibliography file (conference contribution, technical manual, patent, standard).
13. Experiment with the `\nocite{}` command.
14. Apply Harvard citation style to your document by using the `natbib` package and the `\citep{}` command.

Chapter 5

Using the `muthesis` LaTeX Class

- Use the `muthesis` class file by Graham Gough [7]
- Originated from the Stanford University thesis class
- Fully-compliant with the University theses submission rules:
  - one and a half spaced text
  - margins: left = 40 mm, {right, top, bottom} = 15 mm
  - All pages are numbered, no number is shown on the title page
- Preface sections:
  - title page
  - contents page
  - list of tables, list of figures
  - abstract
  - declaration of honesty
  - statement of qualifications and research
  - custom sections: acknowledgements, author's biography

5.1 Thesis Skeleton

```
\documentclass[12pt,PhD]{muthesis}  % MSc, MPhil, MRes

\begin{document}

\title{The Implications of Playing Negative Characters in Real Life}
\author{Brad Pitt}

\school{School of Drama}
% default: School of Computer Science

\faculty{Faculty of Contemporary Art}
% default: Engineering and Physical Sciences

\principaladviser{George Clooney}
\firstreader{Robert De Niro}
\secondreader{John Travolta}

\beforeabstract
\prefacesection{Abstract}
  This thesis sheds light on a hard life of an actor.

\afterabstract
\prefacesection{Acknowledgements}
  I would like to thank my supervisor and best friend George Clooney...

\afterpreface
\chapter{Introduction}
  ...

\chapter{Conclusions}
  ...

\appendix
\chapter{Author's Contribution to Cinematography}
  ...

\bibliographystyle{plain}
\bibliography{actor,producer,soundtrack}

\end{document}
```

5.2 Handling Large Documents

- Working with large documents use the `\include{file}` or `\input{file}` commands:
  - Instead of

```
\appendix
\chapter{Author's Contribution to Cinematography}
  ...
```

  - Use

```
\appendix
\include{contribution}
```

- Each chapter in its own file:

```
% File: contribution.tex

\chapter{Author's Contribution to Cinematography}
\label{C:contribution}
  ...
```

- Command `\input{}` → short inclusions, file input as is
- Command `\include{}` → long inclusions, new page

Chapter 6

Using the IEEEtran LaTeX Class

- Use IEEEtran class file by Michael Shell [12]: conference, journal, technical note
- "Bare bones" files provided `bare_conf.tex`, `bare_jrnl.tex`, `bare_jrnl_compsoc.tex`
- Begin a journal article:

```
\documentclass[10pt,final,journal,letterpaper,oneside,twocolumn]{IEEEtran}
```

- Paper title:

```
\title{Efficient Algorithms\\for Calculating the Number $\pi$}
```

- Author, membership type, publishing dates and affiliation:

```
\author{John~Smith,%
  \IEEEmembership{Member, IEEE}%
  \thanks{Manuscript received...}%
  \thanks{J.~Smith is with...}%
}
```

- Running headings:

```
\markboth{Journal of Computational Mathematics, Vol.~1, No.~5, May~28, 2012}%
         {Smith: Efficient Algorithms for Calculating the Number $\pi$}
```

- Publication ID:

```
\IEEEpubid{0000--0000/00\$00.00~\copyright~2012 IEEE}
```

- Special paper notices:

```
\IEEEspecialpapernotice{ (Invited Paper) }
```

- Title creation:

```
\maketitle
```

- Abstract inclusion:

```
\begin{abstract}
 \boldmath Efficient computation of the number $\pi$ always has been
  a holy grail of the computational mathematics.
\end{abstract}
```

- Key words:[1]

```
\begin{IEEEkeywords}
  Efficient algorithms, elegant algorithms, number crunching
\end{IEEEkeywords}
```

[1] For an up-to-date list of the IEEE-approved keywords send a blank email to keywords@ieee.org

- Section headings:

```
\section{...}
\subsection{...}
\subsubsection{...}
\paragraph{...}
```

- Drop cap letter:

```
\IEEEPARstart{N}{umbers} have a great importance in peoples' lives...
```

- Citations:

```
First attempts of the efficient $\pi$ calculation
date back to 1593~\cite{Viete93}.
```

- Equations (`equation`):

```
\begin{equation}
  \pi = \frac{4}{k} \, \Big( m \, \cot^{-1}{u} + n \, \cot^{-1}{\nu} \Big)
  \label{E:Machin}
\end{equation}
```

$$\pi = \frac{4}{k}\left(m \cot^{-1} u + n \cot^{-1} v \right) \tag{6.1}$$

- Multiline equations and advanced mathematical notation:

- Load the AMS package:

```
\usepackage[cmex10]{amsmath}  % use true type 1 fonts
% \interdisplaypenalty        % automatic insertion of line breaks
```

- Use environments such as `multline` and `align`

- Floating structures (IEEE requirement): top of the page `[t]`, no floats on the first page

- Double column floats: `figure*` and `table*` environments

- Appendices:

- Single appendix:

```
\appendix[Pseudo-Random Numbers]
```

- Multiple appendices:

```
\appendices
\section{Pseudo-Random Numbers}
\section{Prime Numbers}
```

- Acknowledgements:

```
\section*{Acknowledgements}
```

- Bibliographies:

```
\bibliographystyle{IEEEtran}
\bibliography{IEEEabrv,references}
```

- Biographies:

```
\begin{IEEEbiography}[ { \includegraphics{pic/smith} } ]{John Smith} ...
...
\end{IEEEbiography}
```

- Photo of size 1×1.25 in, 220 dpi, grey-scale, 8 bits per sample
- Use the environment `IEEEbiographynophoto` for pictureless biographies
- Package `IEEEtrantools` enables `IEEEtran` commands and environments for other document classes

Chapter 7

Creating Presentations with `beamer`

- Start a new presentation:

```
\documentclass{beamer}
```

- Create slides with the `frame` environment:

```
\begin{frame}{Theoretical Background}
  ...
\end{frame}
```

7.1 Presentation Skeleton

```
\documentclass{beamer}
\usetheme{Boadilla}

\usepackage{amsmath}

\author[A.~Huxley]{Aldous Huxley}
\institute[UC, Berkeley]{The University of California, Berkeley}
\title{Robots in Household}
\date{June~25, 1962}

\begin{document}

\begin{frame}
  \maketitle
\end{frame}
```

```
\begin{frame}{Advances in Artificial Intelligence since~1950s}
  \begin{columns}
    \column{0.5\textwidth}

    \begin{itemize}
      \item ...
    \end{itemize}

    \column{0.5\textwidth}

    \begin{figure}
      \centering
      \includegraphics[scale=0.1]{../pic/indianhead}
    \end{figure}

  \end{columns}
\end{frame}

\begin{frame}[fragile]{Atomic Commands}

  \verb|drive|   ...\\
  \verb|stop|    ...\\
  \verb|standby| ...\\
\end{frame}

\begin{frame}{Major Hurdles}
  \begin{block}{Ethics}
    ...
  \end{block}

  \begin{block}{Governmental Support}
    ...
  \end{block}
\end{frame}

\begin{frame}{Main Competitors}
  \begin{itemize}
    \item \alert{USSR}
    \item \alert{Japan}
  \end{itemize}
\end{frame}

\end{document}
```

Chapter 8

Creating Posters with `sciposter`

- Start a new poster:

```
\documentclass{sciposter}
```

- Use standard preamble commands:

```
\title{Propagation of Sound Waves under Water}
\author{Jim White, Joe Black}
\institute{School of MACE, The University of Manchester}
\email{\{white, black\}@postgrad.manchester.org}
```

8.1 Poster Skeleton

```
\documentclass[plainsections]{sciposter}

\usepackage{multicol}

\title{Underwater Propagation\\of Sound Waves}
\author{Jim White, Joe Black}
\institute{School of MACE, The University of Manchester}
\email{\{white, black\}@postgrad.manchester.org}

\setlength{\columnseprule}{0pt}  % remove vertical column separator line

\begin{document}

\conference{School of MACE, Postgraduate Poster Conference}

\maketitle

\begin{multicols}{2}  % begin of multicolumn environment

\section{Introduction}

\begin{itemize}
  \item ...
\end{itemize}
```

```
\section{Future Work}

\begin{itemize}
  \item ...
\end{itemize}

\end{multicols}       % end of multicolumn environment
\end{document}
```

- Use other floating environments (`figure`, `table`) normally

Chapter 9

Creating Indices with `makeidx`

- Index—alphabetic list of words and phrases with the corresponding page numbers
- Index creation: package `makeidx`, program `makeindex`
- Load package `makeidx`
- Place the `\makeindex` command into the LaTeX file preamble
- Identify words and phrases for indexing → command `\index{key}`

```
Albert Einstein\index{Einstein, Albert} developed
the Relativity Theory\index{Relativity Theory}...
```

- Same index key on different pages → multiple page numbers in the index
- Highlight main index entry in bold:

```
The Relativity Theory\index{Relativity Theory|textbf} considers...
```

- Showing index (end of document) → command `\printindex`
- Proofreading: package `showidx` → index entries in the left margin

9.1 Document Skeleton

```
\documentclass{article}

\usepackage{makeidx}
\makeindex

% \usepackage{showidx}

\begin{document}

\author{Jim Floyd}
\title{On the Relativity Theory}

\maketitle

\section{Introduction}

Albert Einstein\index{Einstein, Albert} developed
the Relativity Theory\index{Relativity Theory|textbf}...

\printindex

\end{document}
```

- Change in the compilation procedure:

```
(pdf)latex     article.tex
     bibtex    article
     makeindex article
(pdf)latex     article.tex
(pdf)latex     article.tex
```

- Use style files to modify the default appearance of the index:

```
makeindex -s <style_file> article
```

- Style files available:

bbglo.ist	bbind.ist	bibref.ist	classic.ist	confproc1.ist
confproc2.ist	din.ist	docindex.ist	dtk-adr.ist	dtk-idx.ist
dtx.ist	gatech-thesis-index.ist	gbibarts.ist	gglo.ist	gind.ist
gmglo.ist	icase.ist	iso.ist	l3doc.ist	latex.ist
laws.ist	lowercase-headers.ist	lv.ist	math.ist	mbgglo.ist
mbgind.ist	minitoc-fr.ist	minitoc.ist	mkind.ist	nomencl.ist
nomentbl.ist	nostarch.ist	plaintex.ist	puncts.ist	repeatindex.ist
songbook.ist	stxglo.ist	stxind.ist	tex.ist	uppercase-headers.ist

Chapter 10

Creating Glossaries with `glossaries`

- Load package `glossaries` to create lists of glossaries, acronyms and symbols
- Glossary creation: package `glossaries`, program `makeglossaries`[1]
- Place the `\makeglossaries` command into the LaTeX file preamble
- Define a glossary term: `\newglossaryentry{label}{settings}`

```
\newglossaryentry{electron}
{
}
```

- Define a symbol:

```
\newglossaryentry{pi}
{
}
```

- Define an acronym:

```
\newacronym{cem}{CEM}{Computational Electromagnetics}
```

- Place term definitions in a separate file, e.g. `acronyms.tex`
- Input term definitions: `\input{acronyms}`
- Use defined terms in a document:

```
\Gls{label}, \gls{label}, \Glspl{label}, \glspl{label}
```

- `\G...` writes a term with the capital letter
- `\...pl` writes a plural form of the term

```
\Gls{cem} deals with numerical methods such as the \gls{fdtd} method...
```

- Showing glossaries (end of document): command `\printglossaries`

[1] On Windows: Perl is necessary for `makeglossaries` to work.

10.1 Document Skeleton

```
\documentclass{article}

\usepackage[toc,acronym]{glossaries}
\makeglossaries

\newacronym{cem}{CEM}{Computational Electromagnetics}
\newacronym{fdtd}{FDTD}{Finite-Difference Time-Domain}

\author{Jack Flapper}
\title{Overview of Computational Electromagnetics}

\begin{document}

\maketitle
\tableofcontents

\section{Introduction}

\Gls{cem} deals with numerical methods such as the \gls{fdtd} method...

\newpage
\printglossaries

\end{document}
```

- Change in the compilation procedure:

```
(pdf)latex          article.tex
     bibtex         article
     makeindex      article
     makeglossaries article
(pdf)latex          article.tex
(pdf)latex          article.tex
```

Chapter 11

Conclusion

- Useful packages to pay attention to: `url`, `geometry`, `hyperref`, `listing`, `algorithmicx`
- Finding information online:
  - LaTeX Wikibook
  - CTAN package repository
  - LaTeX users group of the University: latex-users@listserv.manchester.ac.uk
  - Online forums (http://www.latex-community.org)
  - Nicola Talbot's book "Using LaTeX to write a PhD thesis"
- Dealing with LaTeX errors and warnings
- Importance of reading documentation files
- Advice: do not change the default typesetting
  - Author takes care about the *content*
  - LaTeX takes care about the *layout*
- Typography: Chicago manual of style, Oxford manual of style, the Economist Style Guide

Bibliography

[1] I. N. Bronstein and K. A. Semendiaev, *Reference on Mathematics for Engineers and Students of Technical Universities*, 15th ed., A. Z. Ryvkin, S. N. Akhlamov, and O. A. Sigal, Eds. 117071 Moscow B-71, Lenin Prospect 15: "Physical–Mathematical Literature" RAN, Mar. 3, 1998, (in Russian).

[2] M. Y. Vygodsky, *Reference on Higher Mathematics for Universities and Technical Universities*, 14th ed. 121099 Moscow, a/ya 920: OOO "Bolshaya Medveditsa", AOZT "Vek", Aug. 20, 1997, (in Russian).

[3] A. Taflove, Ed., *Advances in Computational Electrodynamics: The Finite-Difference Time-Domain Method*, ser. Artech House antenna library. 685 Canton Street, Norwood, MA 02062: Artech House, Inc., 1998.

[4] D. E. Knuth, *The TEXbook*. Addison-Wesley Professional, Jan. 11, 1984.

[5] L. Lamport, *LATEX Document Preparation System, Users Guide & Reference Manual*, Oct. 1985.

[6] (2007, Jan. 17) Key Facts Sheets. United Kingdom Census 2001. Archived from the original on Jul. 21, 2006. Retrieved Jul. 10, 2007. [Online]. Available: http://www.manchester.gov.uk

[7] G. D. Gough. (2011, Aug. 25) The University of Manchester LATEX Class File `muthesis`. The University of Manchester, UK. [Online]. Available: http://www.ctan.org/tex-archive/macros/latex/contrib/muthesis

[8] (2012, Jun. 10) Academic ranking of world universities 2011. Center for World-Class Universities of Shanghai Jiao Tong University (CWCU). [Online]. Available: http://www.shanghairanking.com/ARWU2011.html

[9] (2012, Apr. 16) LATEX Wikibook. [Online]. Available: http://www.wikibooks.org

[10] (2007, Jul. 10) United Kingdom Census 2001. Manchester (Local Authority). [Online]. Available: neighbourhood.statistics.gov.uk

[11] CO_2 Emissions from Fuel Combustion Population 1971–2008. IEA OECD World Bank. (original population ref. OECD/World Bank, e.g., in IEA Key World Energy Statistics 2010, page 57).

[12] M. Shell, *How to Use the IEEEtran LATEX Class*, IEEE, Jan. 11, 2007, ver. 1.7. [Online]. Available: http://www.michaelshell.org/tex/ieeetran/

[13] ——. The IEEEtran BibTeX style. IEEE. [Online]. Available: http://www.michaelshell.org/tex/ieeetran/bibtex/

[14] H. Brezis, *Functional Analysis, Sobolev Spaces and Partial Differential Equations*. 233 Spring Street, New York, NY, 10013, USA: Springer Science+Business Media LLC, 2010.

[15] K.-J. Kim, *Beamer v3.0 Guide*, Nov. 4, 2004, ver. 3.0.

[16] M. H. Wilkinson, *Manual for Preparation of Posters of any size using `sciposter.cls`*, University of Groningen, Institute for Mathematics and Computing Science, Aug. 18, 2006, ver. 1.18.

[17] R. Courant, K. Friedrichs, and H. Lewy, "On the partial difference equations of mathematical physics," *IBM Journal*, pp. 215–234, March 1967.

[18] J.-P. Bérenger, "A FDTD subgridding based on Huygens surfaces," in *IEEE AP-S International Symposium*, Washington D.C., USA, 2005.

[19] A. Taflove and S. C. Hagness, *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, 3rd ed. Artech House, 2005.

[20] M. Abaļenkovs, "Huygens Subgridding for the Frequency-Dependent–Finite-Difference Time-Domain Method," Ph.D. dissertation, The University of Manchester, School of Electrical and Electronic Engineering, Sackville Street Building, Manchester, M60 1QD, United Kingdom, Nov. 24, 2011. [Online]. Available: https://www.escholar.manchester.ac.uk/item/?pid=uk-ac-man-scw:137344