**\LaTeX**

Markus Kuhn

Computer Laboratory, University of Cambridge

https://www.cl.cam.ac.uk/teaching/2021/TeX+MATLAB/

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**\LaTeX** – a document formatter

\LaTeX: a macro package for the TeX (τεχ, "tech") typesetting system

▶ excellent facilities for mathematical notation
▶ de-facto standard for preparing scientific publications in mathematical, physical, computing and engineering disciplines

**History:** Donald Knuth (Stanford CS) developed TeX in mid 1970s, in SAIL, to typeset his "Art of Computer Programming" books, reimplemented it in Pascal in the mid 1980s (WEB, literate programming), was later ported to C. Leslie Lamport (SRI, DEC) wrote \LaTeX in early 1980s. Both now community maintained as TeX Live open-source distribution.

Classic processing steps:

```
\texttt{tex} \rightarrow \texttt{dvi} \rightarrow \texttt{ps} \rightarrow \texttt{pdf}
```

Modern alternative:

```
\texttt{pdflatex} \rightarrow \texttt{pdf}
```

These slides: prepared using the \LaTeX beamer class.

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**\LaTeX** – resources

**Recommended introduction**


**Installation**

- Debian/Ubuntu: \texttt{apt-get install texlive}
- macOS: https://www.tug.org/mactex/

**More documentation**

Online tutorials:
https://www.latex-project.org/help/
TeX Frequently Asked Questions list:
https://texfaq.org/

For advanced users:

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**\LaTeX** – features and benefits

▶ Most popular mathematical typesetting language (subset imitations now also in: Word, MathJax, MediaWiki, etc.)
▶ Encourages logical markup ⇒ helps to maintain consistent style
▶ Plain-text source ⇒ easy to collaborate via version-control systems
▶ Command-line tool ⇒ easy to automate build (make)
▶ Use any plain-text editor you like (Emacs, vi, TeXworks, Word, etc.)
▶ Robust for large, complex documents (PhD thesis, books, etc.)
▶ Highly extensible (a Turing-complete macro programming language) ⇒ vast collection of add-on packages for special typesetting needs (figures, logic proofs, pseudo code, circuit diagrams, flow charts, chemical formulae, slides, chess positions, etc.)

\begin{verbatim}
\usepackage{skaknew}
\usepackage{skak}
\usepackage{mainline}
\usepackage{chessboard}
\end{verbatim}

▶ Computer Modern, etc. ⇒ free font families
▶ Mature, free, portable, open source, used by many science publishers
\documentclass[12pt]{article}
\setlength{\textwidth}{75mm}
\begin{document}
\title{\LaTeX{} -- a summary}
\author{Markus G. Kuhn}
\date{11 October 2019}
\maketitle
\thispagestyle{empty}

\section{Introduction}
Mathematical formulæ such as $e^{i\pi} = -1$ or even
\[ \Phi(z) = \frac{1}{\sqrt{2\pi}} \int_0^x e^{-\frac{1}{2} x^2} \]
were a real ‘pain’ to typeset until \textsc{Knuth}’s text formatter \TeX{} became available \cite{Knuth86}.

\begin{thebibliography}{9}
\bibitem{Knuth86} Donald E. Knuth: The \TeX{}book. Addison-Wesley, 1986.
\end{thebibliography}
\end{document}
Grouping

The curly braces \{ and \} serve two purposes in \TeX:

- **Lexical scope:** a \{ saves current state on a stack and \} restores it, therefore state changes (e.g., font switch, variable assignment) inside a \{ ... \} group last only until the \}.

  This is a \texttt{\{bfseries bold\}} statement.

- **Commands and macros read for each argument either a single character or a group enclosed by \{ and \}:

Typeset \texttt{\{textbf{M}} in \texttt{\{textbf{boldface}\}}.

Typeset \texttt{M} in \texttt{boldface}.

\TeX macros can have optional arguments, which are enclosed by \[ ... \]:

\texttt{\{makebox[80mm]\[c\}{this is centered in a box 80 mm wide}}

Typewriting versus typesetting

The ASCII (ISO 646) 7-bit character set has only 94 graphic characters:

```
! "#$%&'()*+,-./0123456789:;<=>? @ABCDEFGHIJKLMNOPQRSTUVWXYZ[\]^_`abcdefghijklmnopqrstuvwxyz{|}~
```

They were chosen to cover the character repertoire of US typewriters and teletype printers. The standards committee added a few more symbols (\{\[\]\{\})\ in the hope that they will be useful for programming.

\TeX defines a number of shortcuts and macros to access the much larger set of "typographic" characters used by book printers.

These typographic characters still cannot be found on standard PC keyboard layouts, which were designed for 7-bit ASCII.
Dashes

ASCII provides only a single combined hyphen-minus character, but typesetters distinguish carefully between several dash characters:

- ⇒ - hyphen U+002D
-- ⇒ – en dash U+2013
--- ⇒ — em dash U+2014
$-$ ⇒ − minus U+2212

The hyphen (-) is the shortest of these and is used to combine separate words or split words across line-breaks.

The en dash (–) is often used to denote a range of numbers (as in pages 64–128), or—as in this example—as a punctuation dash.

The em dash is used—like this—as a punctuation dash, often without surrounding space, especially in US typography.

The minus (−) is a mathematical operator, whose shape matches the plus (+), unlike the hyphen or dashes. Compare: -+, −+, −−+, −−−+.

Non-ASCII Symbols

j \)` Å \AA ŋ \P
l \)` ø \o ŋ \dag
oe \oe Ø \O
Œ \OE ł \l © \copyright
æ \ae Ł \Ł £ \pounds
Æ \AE Ø \s \ldots
â \aa ¥ \S

With \usepackage[utf8]{inputenc} such characters can also be entered as UTF-8 Unicode.

Combining characters

ó \'o ð \ö ó \s o \t{oo}
ô \’o ó \. o \c{oo}
ô “\o ð \u{o} o \d{oo}
ô ”\o ð \n{o} o \b{o}
ô “\o ð \H{o}

Quotation marks

Typewriters and ASCII offer only unidirectional ‘single’ and “double quotation marks, while typesetters use ‘curly’ and “directed” variants.

\TeX input files use the single quotation mark (‘) and the grave accent (‘) to encode these, as well the mathematical ‘prime’ marker and the French accents:

· ⇒ ‘ left quote U+2018
‘· ⇒ ’ right quote U+2019
‘‘ ⇒ “ left doublequote U+201C
‘‘· ⇒ ” right doublequote U+201D
$\'\$ ⇒ ′ prime U+2032
\'u ⇒ ú acute accent U+00E4
\"u ⇒ ´u grave accent U+00F0

The apostrophe (it’s) is identical to the right single quotation mark.

In some older terminal fonts (especially of US origin), the ‘ and ’ characters have a compromise shape somewhere between the quotation marks ‘ ’ and the accents ‘’.

Space – the final frontier

Traditional English typesetting inserts a larger space at the end of a sentence. \TeX believes any space after a period terminates a sentence, unless it is preceded by an uppercase letter. Parenthesis are ignored.

This works often: J. F. Kennedy’s U.S. budget. Look!

But not always: E.g. NASA. Dr. K. Smith et al. agree.

To correct failures of this heuristic, use

- ⇒ no-break space
\( ⇒ force normal space
\@ ⇒ following punctuation ends sentence

as in

E.g. NASA\@. Dr.’K. Smith et al.\ agree.

Or disable the distinction of spaces with \frenchspacing.
Structure of a \LaTeX document

First select a document class and its options, e.g. with
\begin{verbatim}
\documentclass[12pt,a4paper]{article}
\end{verbatim}


Publishers often provide authors with their own class as a *.cls file. Appendix A of The \LaTeX Companion explains how to write new class files. A popular class for presentation slides: beamer

Environment: group delimited by \begin{name} and \end{name}, e.g.
\begin{verbatim}
\begin{document}
...
\end{document}
\end{verbatim}

Common environments: abstract, center, verbatim, itemize, enumerate, quote, tabular, equation, ...

Mark headings with
\begin{verbatim}
\section{...}
\subsection{...}
\paragraph{...}
\end{verbatim}

and \LaTeX will take care of font sizes, numbering, and table of contents.

Verbatim text: quoting source code

\begin{verbatim}
$initial = substr($record->{'name'}, 0, 1);
\end{verbatim}

Do not indent a verbatim block (prints all whitespace). Keep \end{verbatim} on its own line.

Source code with math mode: \texttt{\usepackage{alltt}} is similar to verbatim, but keeps the meta characters \\
, so you can still switch fonts and typeset mathematical expressions:
\begin{verbatim}
\begin{alltt}
for \(i:=1,\ldots,n\) print \(x[i]\)
\end{alltt}
\end{verbatim}

Inline strings: use \verb+text+ to quote text inside a paragraph, where + is any character that does not occur in text. This also disables meta characters, preserves whitespace, and switches to a typewriter font.

You can't use \verb in command arguments, use \texttt{\texttt} instead.
The \verb++text+ variant prints spaces as \texttt{\texttt{}}. Fix single quotation mark: \texttt{\texttt{}}.

\LaTeX list environments

\begin{verbatim}
\begin{itemize}
\item Mammals
  \begin{itemize}
  \item Dogs
  \item Ponys
  \end{itemize}
\item Insects
\end{itemize}
\end{verbatim}

\begin{verbatim}
\begin{enumerate}
\setcounter{enumi}{-1}
\item Fruits
  \begin{enumerate}
  \item Apples
  \item Cucumbers\label{c}
  \end{enumerate}
\item Veggies
  \begin{verbatim}
  (see also \ref{c})
  \end{verbatim}
\item Veggies
\end{enumerate}
\end{verbatim}

Package \texttt{enumitem} adds many configuration options to these environments. (\texttt{texdoc enumitem})

Tweaking and extending \LaTeX

\LaTeX behaviour can be changed by overwriting predefined variables and macros. This can be done
\begin{itemize}
  \item in the \texttt{preamble} (between the \texttt{\documentclass{...}} and \texttt{\begin{document}} lines) ⇒ for the entire document
  \item anywhere in the document ⇒ the effect will last only until the end of the current group (i.e., the next \texttt{...} or \texttt{\end{...}})
\end{itemize}

Packages

A huge collection of extension packages exists for \LaTeX. Some merely define additional macros and environments, others rewrite parts of \LaTeX's internal machinery. For example, adding to the \texttt{preamble}
\begin{verbatim}
\usepackage{hyperref}
\end{verbatim}

loads all the macros and settings defined in the \texttt{hyperref.sty} package.

\texttt{hyperref} adds new macros, such as \texttt{\url{...}} for typesetting URLs, but also automatically turns every reference to a page, section, or bibliographic entry into a hyperlink.

Documentation: \texttt{texdoc packagename} e.g. \texttt{texdoc geometry}
Example: changing page layout geometry

Adjust margins manually, via numerous length variables:
\setlength{\oddsidemargin}{-0.4mm} % 25 mm left margin
\setlength{\evensidemargin}{\oddsidemargin}
\setlength{\textwidth}{160mm} % 25 mm right margin
\setlength{\topmargin}{-5.4mm} % 20 mm top margin
\setlength{\headheight}{5mm}
\setlength{\headsep}{5mm}
\setlength{\footskip}{10mm}
\setlength{\textheight}{237mm} % 20 mm bottom margin

More comfortable:
\usepackage[vmargin=20mm,hmargin=25mm]{geometry}
The \texttt{geometry.sty} package automatically recalculates any dimensions not specified.

Make paragraphs not indented at the first line, but spaced apart slightly:
\setlength{\parindent}{0mm}
\setlength{\parskip}{\medskipamount}
Or just:
\usepackage{parskip}

Mathematical typesetting

In \TeX, mathematical formulas are formatted in a completely different mode from that used for normal text.

Inline formulas such as \( a_n \) (\$a_n\$) that appear as part of a normal paragraph have to be surrounded with $...$ or \(...\), while \[...\] produces a displayed formula, such as
\[ F_n = F_{n-1} + F_{n-2} \]

In \texttt{math italic} mode
▶ space characters are ignored; \TeX\ adds its own space around operators based on heuristics; manually add \texttt{thinspace} with "\,"
▶ a special \texttt{math italic} font is used, with different inter-character spacing,
designed for \texttt{single-letter variables} concatenated in products
▶ many additional macros for special symbols are defined

Math \texttt{italic} is very \texttt{different} and not suitable for writing words or units!
Use \texttt{\mathrm{...}} around words, as in \$v_{\text{diff}}\$ → \texttt{v\text{diff}}.

Macros for common function symbols (constants: upright font!):
max_{x\in\mathbb{R}}\{\log_2(\cos x)\}

Macros for neatly aligning multiple equations: \usepackage{amsmath}, see \texttt{texdoc amsldoc}.

Greek letters symbols

| \Gamma | \delta | \pi |
| \Delta | e | \rho |
| \Theta | \varepsilon | \sigma |
| \Lambda | \zeta | \varsigma |
| \Xi | \eta | \tau |
| \Pi | \theta | \varrho |
| \Sigma | \vartheta | \varsigma |
| \Upsilon | \iota | upsilon |
| \Phi | \kappa | \phi |
| \Psi | \lambda | \varphi |
| \Omega | \mu | \chi |
| \alpha | \nu | \psi |
| \beta | \xi | \omega |
| \gamma | o |

Binary operators

| \pm | \mp | \lhd | \oplus |
| \mp | \mp | \cap | \ominus |
| \setminus | \cup | \otimes |
| \cdot | \cdot | \uplus | \oslash |
| \times | \sqcup | \bigcirc |
| \ast | \ast | \bigcirc |
| \star | \star | \bigcirc |
| \diamond | \bigcirc | \bigcirc |
| \circ | \circ | \bigcirc |
| \bullet | \vee | \bigcirc |
| \div | \wedge |
| \langle | \rangle | \bigtriangleup |
| \rangle | \rangle | \bigtriangledown |

Mathematical symbols

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Mathematical symbols

Relations
\leq \preceq \ll \subseteq \sqsubseteq \in \vdash \smile \frown \sqsubset \geq \succ \preceq \gg \supset \preceq \sqsubset \equiv \sim \simeq \asymp \approx \cong \bowtie \propto \models

\not \leq \not \preceq \not \ll \not \subseteq \not \sqsubseteq \not \in \not \vdash \not \smile \not \frown \not \sqsubset \not \geq \not \succ \not \preceq \not \gg \not \supset \not \preceq \not \sqsubset \not \equiv \not \sim \not \simeq \not \asymp \not \approx \not \cong \not \bowtie \not \propto \not \models

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

\not \leftarrow \not \Leftarrow \not \rightarrow \not \Rightarrow \not \leftrightarrow \not \Leftrightarrow \not \mapsto \not \hookrightarrow \not \leftharpoonup \not \leftharpoondown \not \rightleftharpoons \not \longleftarrow \not \Longrightarrow \not \longrightarrow \not \longmapsto \not \hookrightarrow \not \rightharpoonup \not \rightharpoondown \not \leadsto \not \uparrow \not \Uparrow \not \downarrow \not \Downarrow \not \updownarrow \not \uparrow \not \nearrow \not \searrow \not \swarrow \not \nwarrow

Large operators and delimiters
\sum \prod \coprod \int \bigcap \bigcup \bigodot \bigotimes \bigoplus \bigsqcup \bigsqcup \bigvee \bigwedge \bigwedge \bigvee
\bigbraceleft \bigbraceright \bigbrcleft \bigbrcright \bigbraceleft \bigbraceright \bigbrcleft \bigbrcright
\ldots \cdots \vdots \ddots

Use \ldots in a, b, \ldots, z, but \cdots in a + b + \cdots + z. Never write ...
Mathematical symbols

Alternative names

\ne \neq \le \to \ge \gets \owns \land \lor

Stacking things

\textstyle\overline{a-b} = \overbrace{a-b}_c
\textstyle\underline{a-b} = \underbrace{a-b}_c
\textstyle\left\{
\begin{array}{cl}
a^{2^{2^2}}, & a \ge 0 \\
-\frac{1}{a}, & a < 0
\end{array}\right.

Including graphics

DVI only supports characters and filled rectangles, but dvips and pdftex also understand embedded "special" instructions that provide more.

Embedded PostScript (EPS) vector graphics:

Normal PostScript files (*.ps) produce a sequence of pages. An EPS file describes only an image and is meant to be included into a PostScript page. EPS files lack instructions to output paper, but define a rectangular "bounding box", using special %BoundingBox: comments.

Load the graphicx extension of LaTeX by adding

\usepackage{graphicx}

to the preamble. Then write

\includegraphics{filename.eps}

wherever you want to include the graphics file into your text.

In pdflatex, the graphicx package allows you to include graphics from PDF (vector graphics), JPEG (photos) and PNG (bitmap) files:

\includegraphics{filename.pdf}

Postscript/PDF graphics facilities

Applying coordinate transforms:

The graphicx package provides access to the geometric transform capabilities of the PostScript and PDF languages:

\scalebox{0.8}{\includegraphics{diagram.pdf}}
\includegraphics[height=60mm]{screenshot.png}
\includegraphics[width=0.9\linewidth]{photo.jpg}
\resizebox{190mm}{60mm}{becomes 19 cm $\times$ 6 cm large}
\resizebox{190mm}{!}{this becomes 19 cm wide}
\rotatebox{180}{this is upside down!}

Changing colours:

The color package also uses Postscript/PDF special commands:

This text is \textcolor{red}{printed in red} if ...

This text is printed in red if you include \usepackage{color}.

Default: \definecolor{red}{rgb}{1,0,0}

Figures and references

Larger diagrams interfere with page breaking. They are best placed into a figure environment, such that LaTeX can move them around. Example:

\begin{figure}
  \includegraphics[width=0.6\linewidth]{photo.jpg}
  \caption{This photograph shows the experimental setup.}
  \label{fig:expsetup}
\end{figure}

The automatically assigned figure number can be quoted as in:

See also Figure~\ref{fig:expsetup} (page~\pageref{fig:expsetup}).

The \label{...} command can also be used after \section{...}, \subsection{...}, etc. and inside \begin{equation} ... \end{equation} to assign symbolic names to section and equation numbers, which can then be resolved via \ref{...} or \pageref{...}.

No need to manually renumber figures, sections, or equations!
Build tools for \LaTeX

To make sure \texttt{\label} references and tables of contents use the correct numbers, it may be necessary to call \texttt{latex} twice. It will output “Rerun to get cross-references right” in this case.

The following implicit Makefile rule takes care of this:

```makefile
.DELETE_ON_ERROR:

%.pdf %.aux %.idx: %.tex
  pdflatex $<
  while grep 'Rerun to get ' $*.log ; do pdflatex $< ; done
```

An alternative is the “\texttt{latexmk}” tool, which automatically determines dependencies (e.g. from \texttt{\includegraphics}) and recompiles \LaTeX documents where file modification timestamps indicate that this is necessary.

Graphics editor \texttt{xfig}

- Its \texttt{*.fig} files have a simple plain-text format that can be edited manually, script generated, and leads to useful diffs.
- Can export \texttt{*.eps} or \texttt{*.pdf} files
- Can also produce figures in which \LaTeX is used to fill in all the text. This provides math mode, macros, symbols, references, fonts that match the main text, etc.

Ask \texttt{xfig} to export a \texttt{*.psext} + \texttt{*.psext_t} file pair. The \texttt{*.psext} file lacks the text parts of the figure. The \texttt{*.psext_t} file contains \LaTeX commands that first load the \texttt{*.psext} image, and then add all the text in the figure. Select the “special text” mode in \texttt{xfig} to enable \LaTeX metacharacters. Use \texttt{\include{*.psext_t}} to add such a figure in your document. (PDF equivalent: \texttt{*.pdftex} + \texttt{*.pdftex_t})

- Command-line export tool (e.g., for Makefile): \texttt{fig2dev}
  ```
  %.eps: %.fig
    fig2dev -L eps $< $@
  
  %.psext %.psext_t: %.fig
    fig2dev -L psext_t -p $*.psext $< $*.psext_t
    fig2dev -L psext $< $*.psext
  
  fig2dev -L pdftex %.pdftex_t %.fig
    fig2dev -L pdftex_t -p $*.pdftex $< $*.pdftex_t
    fig2dev -L pdftex $< $*.pdftex
  ```

Other graphics tools: TikZ, pnm2tops, Inkscape, MATLAB, R, gnuplot, Python+matplotlib

Bibliographic references

Academic writing: detailed references to prior work

- to support arguments
- to document familiarity with the field
- to help newcomers to the field
- to give due academic credit
- to join the bibliometric graph of the field (recommendation systems)
- to trigger notifications to cited authors (e.g. Google Scholar alerts)

A bibliographic reference needs to contain all information needed to help readers (and increasingly search engines!) to unambiguously identify and locate the text referred to. Minimum: First two authors, full title, date, indication of type of publication (usually implicitly via other details).

Inter-library loan required many details: names and location of publishers or the volume, issue and page numbers in printed journals. Today, most readers retrieve scientific publications (with the exception of books) digitally, so online identifiers such as URIs or DOIs are more important instead.

Many URLs (e.g., to author’s home pages, “grey literature”) do not last long, but can still later be retrieved via archival services (e.g., archive.org). Therefore: accompany URLs with the date on which you accessed them. Try to HTTP redirect your own URLs when moving web space.

Bibliographic references – styles

Four widely used styles:

- short-title – most common in books on humanities, e.g. “Hart, \textit{Hart’s Rules}, p. 52”
- author-date – most common in science and social science, e.g. “Goossens (1997)” or “(Goossens, 1997b)”.
- author-number – follows the name of the author(s) with a per-author number (rare with \LaTeX), e.g. “Goossens (2)”
- number-only – all publications sequentially numbered in bibliography, made popular by \LaTeX, now very widely used in computer science, e.g. “[67]”.

Collect full references at the end of the document (bibliography), each chapter, or page of first mention (footnotes).

With number-only bibliography: for important work, include author(s) name and year in first mention in the text. Avoid abusing numerical references like a noun (bad: “as shown by [17]”, nice: “as Knuth showed in 1988 [17]”).

When referencing books, also include a chapter or page number.
Bibliographic references – manual approach

\LaTeX{} can also manage numerical references to a bibliography. Append near the end of your document (usually after conclusions and before appendices) your list of bibliographic items, assigning each an alphanumeric identifier:

\begin{thebibliography}{9}
\end{thebibliography}

Then refer to these in the text using \cite{9}:

Finer details on the use of en-dashes are explained by Lamport \cite{Lamport94} or Dupre \cite{Dup98}.
\cite{9} can take an optional note in [], e.g. for a page or section number.
\bibitem{9} can take an optional label in []
\begin{thebibliography}{9} needs a “widest label” as an argument to plan indentation.

Example *.bib file entry

@TechReport{UCAM-CL-TR-123,  
author = {Herbert, John},
title = {Case Study of the {Cambridge Fast Ring ECL Chip} using \{HOL\}},
year = 1988,  
month = feb,  
institution = {University of Cambridge, Computer Laboratory},
number = {UCAM-CL-TR-123}
}

Important: Many U.S. publishers’ house styles use “title case” for publication titles, where most words (other than short articles and prepositions) start with a capital letter.

This form of emphasis is not appropriate for bibliographic references, therefore many Bib\LaTeX{} styles convert titles to lowercase.

Protect names (proper nouns) and acronyms in titles from automatic lowercase-ification by surrounding them with {...}.

Example bibliographic database files and a .bst bibliographic style file (often provided by publisher). Load these as in
\begin{verbatim}
\bibliography{articles,group-refs}
\bibliographystyle{unsrt}
\end{verbatim}
Details:
Lamport, Section 4.3 and Appendix B. \LaTeX{} Companion, Chapter 12.

Exercise 1: Copy file example.tex from slide 9, run “pdflatex example” twice (why?), and then “okular example.pdf &” (Linux) to see the output.

Exercise 2: Read pages 1–64 of the \LaTeX{} book, then write your CV with \LaTeX{}, convert the result into PDF, and put it onto your homepage.

Exercise 3: In a job interview for a position as a subeditor of a technical journal, your skills in spotting typographic mistakes made by \LaTeX{} beginners are tested with this example text:

The \(-7\) dB loss (\(\pm 2\) dB) shown on pp. 7-9 can be attributed to the \(f(t) = \sin(2\pi ft)\) signal , where \(t\) is the the time and \(f = 48\text{Khz}\) is the "sampling frequency".

Can you spot all 14 mistakes? Write down both the probable original incorrect \LaTeX{} source text, as well as a corrected version.