TEX and LATEX
For the Uninitiated*

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The name TEX, pronounced "tech", actually stands for $\tau\epsilon\chi$, the beginning of the Greek word for *art*. It is not a word processor but rather a text-formatter for documents. You can use *any* editor (or word processor) you like to compose a text (ascii) file that is then processed by TEX. The output from TEX is either a *device independent* `.dvi` file or a *page description format* `.pdf` file which can be printed on virtually any printer or displayed on the screen or sent to other personal computers, workstations or mainframes.

Why might you be interested in TEX?

- It produces typographically beautiful documents. For typesetting mathematics, in particular, it has no peer.
- It is universally available. It is standard on UNIX systems and versions exist for MAC and MS-Windows.
- It is supported by a large number of individuals world wide and by a number of Usenet groups.
- It is free. Complete versions for any platform can be obtained from a number of FTP sites.
- It is extremely easy to use for anyone who speaks "mathematics".
- TEX documents are small, ascii files which can be edited by any editor. This means that you can change editors without changing your files. You can quickly send your documents via email without having to "uuencode" or "uudecode" them at either end or worrying about whether your colleague has the right version of the right word processor for your file. You can also use standard utilities such as find, grep, or perl to make your collection of files an easily searched and indexed database.

TEX was designed by Donald E. Knuth, of computer programming fame, in the late 1970's so that he might have a typesetting program worthy of his computer science textbooks. The effort took eight years but was worth it. One writer described the result as the most significant

*If you already know much about TEX you shouldn't be reading this.

event in typesetting in this century and ranked it near the introduction of the Gutenberg press in terms of importance. It has, in fact, become the lingua franca of the scientific community. Scientific papers are routinely prepared and distributed using TEX or LATEX.

Although TEX itself is concerned with the low-level formatting task of laying out text on the page, it is very extensible. Of the many extensions intended to provide higher-level elements such as chapters, sections and footnotes, the two most important have been AmsTEX and LATEX. AmsTEX was developed for the American Mathematics Society and articles submitted for publication in top mathematics journals must now be submitted as AmsTEX files. LATEX was originally intended to provide somewhat less support than AmsTEX for specialized mathematics but more for other document features such as cross-references, tables of contents, indexes and bibliographies. With the advent of the the new LATEX, called LATEX 2_ε during its development, you no longer need to choose — it has the best features of both and more to boot. The details of LATEX (LATEX 2_ε) are set forth in the companion volumes Lamport (1985) and Goosens et al. (2004) and in my personal favorite, Kopka and Daly (2004).

Backslash Commands for Every Purpose

This document was written using LATEX and Vim but any editor or word processor that will save documents as straight ascii (text) documents will do. You can lay out your text in any way that makes it more readable to you — your formating will largely be ignored by LATEX. A group of spaces (one or more), for example, will be treated as a single space, indentions will be ignored and a group of blank lines will become a paragraph break. The editor itself needs very few frills since TEX does nearly everything for you taking its guidance from *backslash commands* that you embed in the text. A footnote, for example, is obtained by merely typing

```
\footnote{This paper was composed using Vim on a Mac running OS X.}
```

at the point[1] where you want the footnote inserted. Note that LATEX handles the numbering and placement automatically. Similarly, The heading of this paper was produced by typing

```
\title{\TeX{} and \LaTeX\\For the Uninitiated\thanks{If you
already know much about \TeX{} you shouldn't be reading this.}}
\author{Daniel A. Graham\thanks{Department of Economics, Duke
University, Durham, NC 27708-0097, (919) 660-1802,
dgraham@acpub.duke.edu.}}
```

at the beginning of the document. Note that LATEX selects the fonts, handles the placement and even provides today's date since I neglected to provide one myself. If you will also notice that LATEX centered the title and author lines without counting the space taken by the asterisk and dagger then you will have begun to see its subtle magic. LATEX handles this sort of detail for you so you can devote yourself to writing.

[1] This paper was composed using Vim on a Mac running OS X.

Mathematical expressions are simplicity itself. To get $z = \lambda x + \Gamma y$, for example, simply type `$z = \lambda x + \Gamma y$`. Note that you only need to know how to spell Greek characters to get them. Equations are just as easy;

```
\begin{equation}
  \label{fundamental}
  F(b)-F(a) = \int_a^b f(x) \, dx
\end{equation}
```

produces the automatically numbered and centered equation:[2]

$$F(b) - F(a) = \int_a^b f(x)\,dx \tag{1}$$

In TEX the underscore is used for subscripts the carrot is used for superscripts. Note the analogous use here for the lower and upper limits of integration.

Equations can then be referenced in the text by using their "labels" so that `Equation~\ref{fundamental}` becomes Equation 1 when printed.[3] Similarly, `Equation~\ref{determinant}` gives Equation 3 even though this equation will not appear until `page~\pageref{determinant}` page 6. Footnote, equation, page and other numbers and references to them are adjusted automatically, of course, when you make additions or deletions.

Backslash commands are available to produce every imaginable iZe of font.

An unbelievable assortment of symbols is also available: ‡, ∨ ∧, ≡, ≥, ≥, ⩾, ⫛, ℵ, and ∅ to name a few. The names are easy to remember too: for ∃, ∀, or ∞ just type `\exists, \forall or \infty`. Access to "math" fonts like $\mathbb{BLACKBOARD\ BOLD}$ and $\mathfrak{Euler\ Fraktur}$ is also easy.

Tables of contents and indexes are trivial. Master bibliographies can be created with reference "keys" such as[4]

```
\bib{ll:1985}{book}{
    author    = {Leslie Lamport},
    title     = {\LaTeX{} --- A Document Preparation System --- User's
        Guide and Reference Manual},
    publisher = {Addison-Wesley},
    year      = {1985}
}
```

and the simple command `\cite{ll:1985}` in a paper is then sufficient not only to produce the appropriate citation to the reference you've labeled "ll:1985" but also to create a reference section in your paper which automatically includes the full reference from the master bibliography.

[2] The \, in this equation gives the nice little space between $f(x)$ and dx.

[3] The ~ is a "non-breaking" space character that assures that the words it connects will not be split by a line break.

[4] This format is used with the *amsrefs* package.

Lists

Enumerated lists couldn't be simpler. The input

```
\begin{enumerate}
\item Sections, subsections, subsubsections, \ldots
\item And enumerated lists are also numbered automatically
  \begin{enumerate}
  \item And each of these can be labeled
  \item And referenced in the text
  \end{enumerate}
\item In exactly the same way that equations are referenced
\end{enumerate}
```

produces

1. Sections, subsections, subsubsections, ...
2. And enumerated lists are also numbered automatically
   (a) And each of these can be labeled
   (b) And referenced in the text
3. In exactly the same way that equations are referenced

Similarly

```
\begin{itemize}
\item \emph{Itemized lists} are also possible. These use symbols such as
  bullets as labels.
\item Still another possibility is a \emph{description list} which
  uses names as labels:
  \begin{description}
  \item[Pareto Improvement.] A change in circumstance which benefits
    at least one person without harming any other person.
  \item[Pareto Optimum.] A situation in which a Pareto improvement is
    not possible.
  \end{description}
\item All forms of lists can be combined.
\end{itemize}
```

yields

- *Itemized lists* are also possible. These use symbols such as bullets as labels.
- Still another possibility is a *description list* which uses names as labels:

Pareto Improvement. A change in circumstance which benefits at least one person without harming any other person.

Pareto Optimum. A situation in which a Pareto improvement is not possible.

- All forms of lists can be combined.

Macros

LaTeX can itself be easily extended. Consider, for instance, the *macro*:

```
\newcommand{\mymatrx}[5]{\left#1 \begin{array}{cccc}
#2_{11}    & #2_{12}   & \cdots & #2_{1 #5} \\
#2_{21}    & #2_{22}   & \cdots & #2_{2 #5} \\
\vdots     & \vdots    & \ddots & \vdots    \\
#2_{#4 1}  & #2_{#4 2} & \cdots & #2_{#4 #5}
\end{array} \right#3}
```

This defines a macro with five arguments numbered #1 through #5. The first and third determine the delimiters (brackets, braces, parenthesis, etc.) that will surround a #4 by #5 matrix with elements corresponding to #2. Now typing

```
\begin{equation}
  \mymatrx [ a ] m n
\end{equation}
```

for example, produces

$$\left[\begin{array}{cccc}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{m1} & a_{m2} & \cdots & a_{mn}
\end{array} \right] \tag{2}$$

This new macro can itself be used within other commands so that

```
\begin{equation}
  \label{determinant}
  \left( \begin{array}{cc}
  \mymatrx | b | q q   &   c_{12} \\
               c_{21}   &   c_{22}
\end{array} \right)
\end{equation}
```

Crop		Plots		
Damage		0	1	2
Trains	0	0	0	0
	1	0	60	120
	2	0	120	240

Table 1: The Coase Example

produces

$$\left(\begin{array}{ccc|c} b_{11} & b_{12} & \cdots & b_{1q} & \\ b_{21} & b_{22} & \cdots & b_{2q} & c_{12} \\ \vdots & \vdots & \ddots & \vdots & \\ b_{q1} & b_{q2} & \cdots & b_{qq} & \\ \hline & c_{21} & & & c_{22} \end{array}\right) \tag{3}$$

Tables

With this input

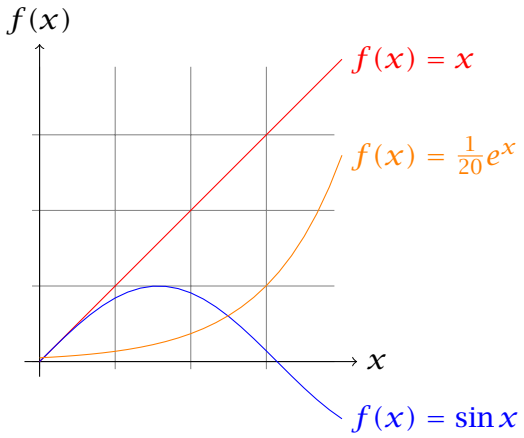
```
\begin{table}
\begin{center}
\begin{tabular}{lr|rcc}
  \multicolumn{2}{l}{Crop}   & \multicolumn{3}{c}{Plots} \\
  \multicolumn{2}{l}{Damage} &  0       &  1       & 2   \\ \hline
  {}         & 0             &  0       &  0       & 0   \\
  Trains     & 1             &  0       &  60      & 120 \\
  {}         & 2             &  0       &  120     & 240 \\ \hline
\end{tabular}
\end{center}
\end{table}
\caption{The Coase Example \label{coase}}
```

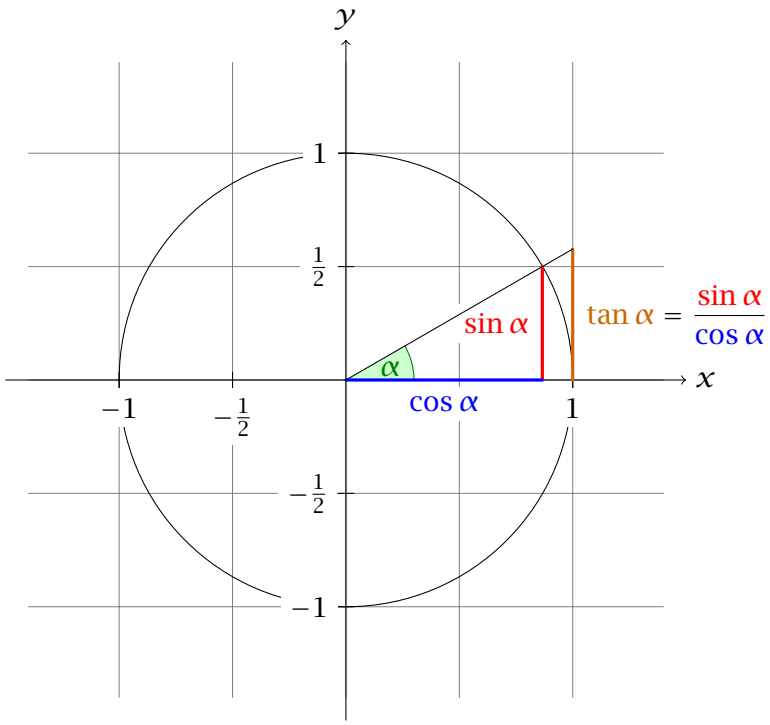
you get `Table~\ref{coase} on page~\pageref{coase}` i.e., Table 1 on page 6. The “table” environment allows the table to “float” to a good nearby spot.

Illustrations

There are a number of possibilities for incorporating illustrations in your documents. Postscript and graphics files in other formats can be incorporated — see Goosens et al. (1997). It is also

possible to construct drawings in the document itself. The “pgf/tikz” package is new, free and one of my favorites. Here is a sample of the possible output followed by the code that produced it.






```
\begin{tikzpicture}[domain=0:4]
\draw[very thin,color=gray] (-0.1,-0.1) grid (3.9,3.9);
\draw[->] (-0.2,0) -- (4.2,0) node[right] {$x$};
\draw[->] (0,-0.2) -- (0,4.2) node[above] {$f(x)$};
\draw[color=red] plot[id=x] function{x} node[right] {$f(x) =x$};
\draw[color=blue] plot[id=sin] function{sin(x)} node[right]%
    {$f(x) = \sin x$};
\draw[color=orange] plot[id=exp] function{0.05*exp(x)} node[right]%
```

```
    {$f(x) =  \frac{1}{20} e^x$};
\end{tikzpicture}


\begin{tikzpicture}[scale=3,cap=round]
% Local definitions
% Colors
\colorlet{anglecolor}{green!50!black}
\colorlet{sincolor}{red}
\colorlet{tancolor}{orange!80!black}
\colorlet{coscolor}{blue}
% Styles
\tikzstyle{axes}=[]
\tikzstyle{important line}=[very thick]
\tikzstyle{information text}=[rounded corners,fill=red!10,inner sep=1ex]
% The graphic
\draw[style=help lines,step=0.5cm] (-1.4,-1.4) grid (1.4,1.4);
\draw (0,0) circle (1cm);
\begin{scope}[style=axes]
\draw[->] (-1.5,0) -- (1.5,0) node[right] {$x$} coordinate(x axis);
\draw[->] (0,-1.5) -- (0,1.5) node[above] {$y$} coordinate(y axis);
\foreach \x/\xtext in {-1, -.5/-\frac{1}{2}, 1}
\draw[xshift=\x cm] (0pt,1pt) -- (0pt,-1pt) node[below,fill=white] {$\xtext$};
\foreach \y/\ytext in {-1, -.5/-\frac{1}{2}, .5/\frac{1}{2}, 1}
\draw[yshift=\y cm] (1pt,0pt) -- (-1pt,0pt) node[left,fill=white] {$\ytext$};
\end{scope}
\filldraw[fill=green!20,draw=anglecolor] (0,0) -- (3mm,0pt) arc(0:30:3mm);
\draw (15:2mm) node[anglecolor] {$\alpha$};
\draw[style=important line,sincolor]
(30:1cm) -- node[left=1pt,fill=white] {$\sin \alpha$} (30:1cm |- x axis);
\draw[style=important line,coscolor]
(30:1cm |- x axis) -- node[below=2pt,fill=white] {$\cos \alpha$} (0,0);
\draw[style=important line,tancolor] (1,0) -- node[right=1pt,fill=white] {
$\displaystyle \tan \alpha \color{black}=
\frac{{\color{sincolor}\sin \alpha}}{\color{coscolor}\cos \alpha}$}
(intersection of 0,0--30:1cm and 1,0--1,1) coordinate (t);
\draw (0,0) -- (t);
\end{tikzpicture}
```

References

Michael Goosens and Frank Mittelbach and Alexander Samarin. 2004. *The LaTeX Companion*, 2nd, Addison-Wesley.

Michael Goosens and Sebastian Rahtz and Frank Mittelbach. 1997. *The LaTeX Graphics Companion*, Addison-Wesley.

Helmut Kopka and Patrick W. Daly. 2004. *A Guide to LaTeX*, 4th, Addison-Wesley.

Leslie Lamport. 1985. *LaTeX — A Document Preparation System — User's Guide and Reference Manual*, Addison-Wesley.