A LaTeX template and user guide

John W. Sanders

Abstract

LaTeX [1] is free typesetting software used to create technical documents in the sciences and mathematics. Most scientific publishers nowadays prefer—and may even require—documents to be prepared in LaTeX. What makes LaTeX better than other word processing programs is its ability to handle copious amounts of equations, tables, figures, citations, and cross-references with ease. It allows the author to focus on the content of the document, rather than wasting time on the minute formatting details. This document serves two purposes: it is both a guide to the most commonly used LaTeX commands, as well as a LaTeX document template, having itself been prepared in LaTeX.

1 Installing LaTeX

LaTeX is available to download free-of-charge. See the official website [1] for specific installation instructions for your operating system. The present document was created with TeXworks [2] operating on Windows. Additionally, a reference manager such as JabRef [3] is recommended for assembling lists of references. See Section 2 below for more details.

2 Citing references

An important part of any technical publication is citing previous work. And anyone who has ever created citations manually knows that it is nothing less than a *nightmare*. Fortunately, LaTeX takes all of the hard work out of it. Start by installing a free reference manager such as JabRef [3]. In JabRef, create (and save) a new library, and add entries for all of the sources you want to cite in your paper. For example, if you wanted to cite Newton's *Principia* [4], you would create a new Book entry with the following field values:

- Title: Philosophiae Naturalis Principia Mathematica
- Publisher: Royal Society of London
- Year: 1687
- Author: Isaac Newton

You will also need to specify a "Bibtexkey," which is a unique identifier that you will use to cite this work. For Newton's *Principia*, we might choose Newton1687 as the Bibtexkey. Once you have all of your sources saved in your library, you are ready to go. To create a list of references at the end of your paper, use the `\bibliography{}` command. For example, if you have saved your JabRef library as references.bib, put `\bibliography{references}` at the end of your document where you want the list of references to appear. Then, wherever you want to cite a reference, use the `\cite{}` command along with the Bibtexkey. If we want to cite Newton's *Principia*, we would type `\cite{Newton1687}`. You can also specify the style of the list of references with a style file. The present document uses the style file asmems4.bst, so we include the command `\bibliographystyle{asmems4}` on the line above `\bibliography{references}`.

3 Equations

One of LaTeX's greatest strengths is its ability to render really nice-looking equations. Numbered equations are created using the `equation` environment, enclosed between the commands `\begin{equation}` and `\end{equation}`. In-line equations are placed between two dollar signs `$$`. For example, Newton's second law of motion states that

$$\mathbf{F} = \frac{d\mathbf{p}}{dt}, \tag{1}$$

where $\mathbf{F}$ is the net force on a particle, $\mathbf{p}$ is the particle's linear momentum, and t is time [4].

Maxwell's equations of electromagnetism are as follows:

$$\text{Gauss's first law:} \quad \oiint_{\partial V} \mathbf{E} \cdot \hat{\mathbf{n}} dA = q/\epsilon_0 \qquad \nabla \cdot \mathbf{E} = \rho/\epsilon_0 \tag{2}$$

$$\text{Gauss's second law:} \quad \oiint_{\partial V} \mathbf{B} \cdot \hat{\mathbf{n}} dA = 0 \qquad \nabla \cdot \mathbf{B} = 0 \tag{3}$$

$$\text{Faraday's law:} \quad \oint_{\partial S} \mathbf{E} \cdot d\mathbf{r} = -\frac{d}{dt} \iint_S \mathbf{B} \cdot \hat{\mathbf{n}} dA \qquad \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \tag{4}$$

$$\text{Ampere's law:} \quad \oint_{\partial S} \mathbf{B} \cdot d\mathbf{r} = \mu_0 j + \mu_0 \epsilon_0 \frac{d}{dt} \iint_S \mathbf{E} \cdot \hat{\mathbf{n}} dA \qquad \nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \tag{5}$$

Here $\mathbf{E}$ and $\mathbf{B}$ are the electric and magnetic fields, respectively; μ_0 and ϵ_0 are the permeability and permittivity of free space, respectively; ∂V is the closed surface bounding an arbitrary volume V; q is the total charge enclosed within V; ρ is the charge density over V; ∂S is the closed curve bounding an arbitrary surface S; j is the total current piercing S; $\mathbf{J}$ is the current density over S; ∇ is the gradient operator; and t is time [5]. Note that LaTeX automatically numbers equations sequentially, without any work required on your part.

The Einstein field equations, which govern how space and time curve in the presence of matter, state that

$$R_{\mu\nu} + \left(\Lambda - \tfrac{1}{2}R\right) g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}, \tag{6}$$

where $R_{\mu\nu}$ are the components of the Ricci curvature tensor, Λ is the cosmological constant, R is the scalar curvature, $g_{\mu\nu}$ are the components of the metric tensor, G is Newton's gravitational constant, c is the speed of light in a vacuum, and $T_{\mu\nu}$ are the components of the stress-energy tensor [6].

The Schrödinger equation of quantum mechanics states that

$$-\frac{\hbar^2}{2m} \nabla^2 \Psi + V\Psi = i\hbar \frac{\partial \Psi}{\partial t}, \tag{7}$$

where $\Psi(\mathbf{r}, t)$ is a particle's wave function, m is the particle's mass, $V(\mathbf{r}, t)$ is the particle's potential energy, i is the imaginary unit, $\hbar$ is the reduced Planck constant, ∇ is the gradient operator, and t is time [7, 8].

Some common mathematical symbols can be found in Appendix A. If you can't find what you're looking for, try Detexify [9]. You can draw the symbol you are looking for and it will generate several suggestions.

4 Floating environments: tables and figures

Tables and figures are examples of *floating environments*, which tend to "float" around as you edit a document.

4.1 Tables

Tables are created using the `table` and `tabular` environments. The location of the table is specified by a string at the beginning of the `table` environment: `t` stands for 'top,' `b` stands for 'bottom,' `h` stands for 'here,' and `p` stands for new 'page.' If you include more than one option, LaTeX will automatically select the one it deems best. You can also force it to use a particular option by including an exclamation point ! at the beginning of the location string. The text justification in each column is specified by a string at the beginning of the `tabular` environment: `l` stands for 'left-justified,' `c` stands for 'centered,' and `r` stands for 'right-justified.' Columns are separated by the ampersand & character, and rows are separated by `\\`. In technical writing, table captions go *above* the corresponding tables. For example, see Table 1 for the Greek alphabet with the corresponding LaTeX syntax.

Table 1. The Greek alphabet. Note that the table caption goes *above* the table.

Letter	Capital	Lowercase	LaTeX syntax
Alpha	A	α	`A, \alpha`
Beta	B	β	`B, \beta`
Gamma	Γ	γ	`\Gamma, \gamma`
Delta	Δ	δ	`\Delta, \delta`
Epsilon	E	ε	`E, \varepsilon`
Zeta	Z	ζ	`Z, \zeta`
Eta	H	η	`H, \eta`
Theta	Θ	θ	`\Theta, \theta`
Iota	I	ι	`I, \iota`
Kappa	K	κ	`K, \kappa`
Lambda	Λ	λ	`\Lambda, \lambda`
Mu	M	μ	`M, \mu`
Nu	N	ν	`N, \nu`
Xi	Ξ	ξ	`\Xi, \xi`
Omicron	O	o	`O, o`
Pi	Π	π	`\Pi, \pi`
Rho	P	ρ	`P, \rho`
Sigma	Σ	σ	`\Sigma, \sigma`
Tau	T	τ	`T, \tau`
Upsilon	Y	υ	`Y, \upsilon`
Phi	Φ	ϕ	`\Phi, \phi`
Chi	X	χ	`X, \chi`
Psi	Ψ	ψ	`\Psi, \psi`
Omega	Ω	ω	`\Omega, \omega`

4.2 *Figures*

Figures are created using the `figure` environment along with the `\includegraphics[]{}` command. The location of the figure is specified by a string at the beginning of the `figure` environment: `t` stands for 'top,' `b` stands for 'bottom,' `h` stands for 'here,' and `p` stands for new 'page.' If you include more than one option, LaTeX will automatically select the one it deems best. You can also force it to use a particular option by including an exclamation point ! at the beginning of the location string. In technical writing, figure captions go *below* the corresponding figures. For example, see Figure 1 for a portrait of Issac Newton.

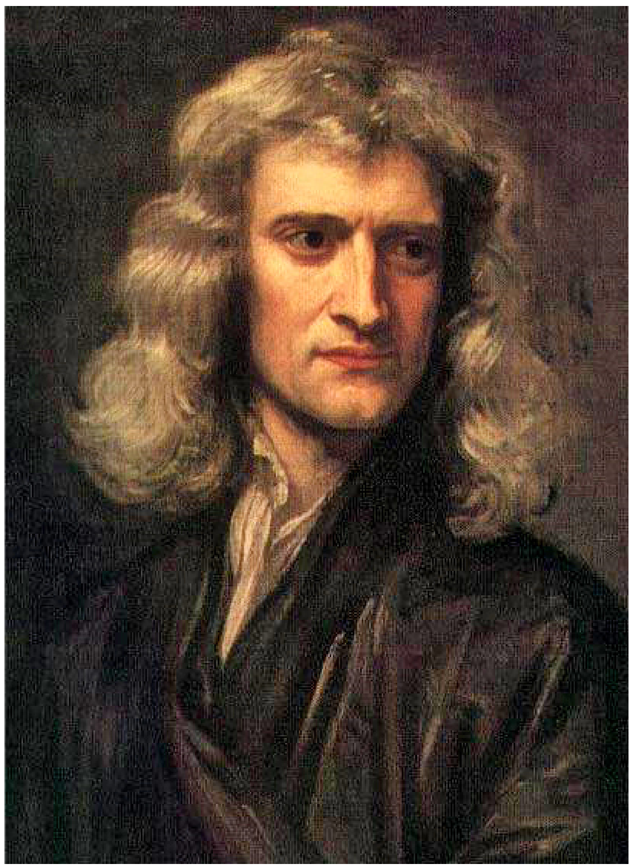
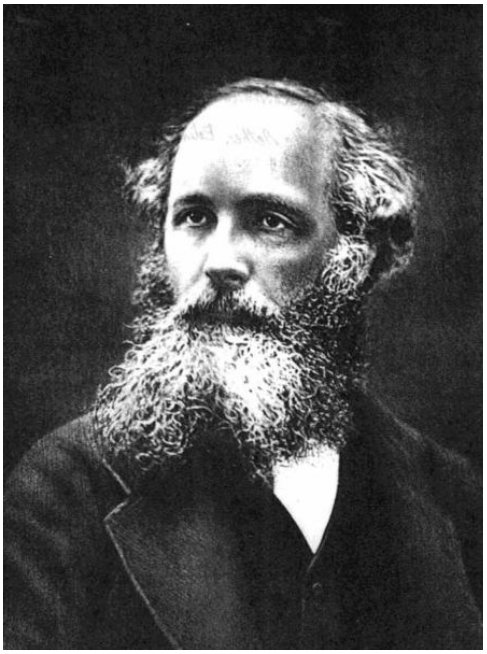
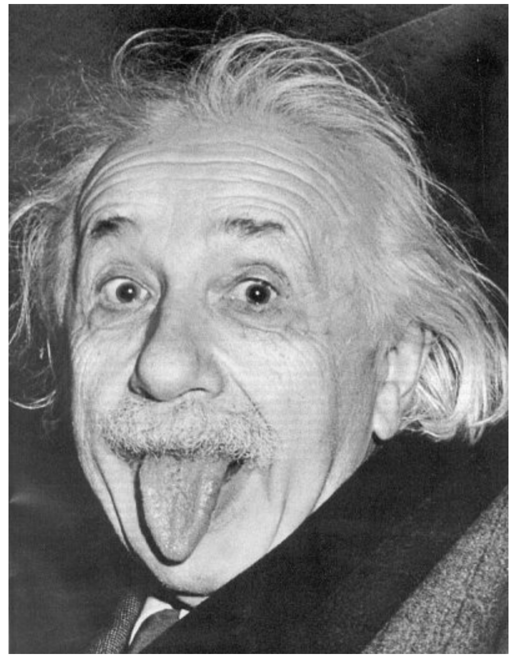


Figure 1. Portrait of Sir Isaac Newton [10]. Note that the figure caption goes *below* the figure.

You can make figures with multiple subfigures using the `subfigure` environment. For example, see Figure 2 for photographs of James Clerk Maxwell, Albert Einstein, and Erwin Schrödinger. Each subfigure can have its own caption and can be referenced independently. For more details about cross-referencing subfigures, see Section 5.



(a)



(b)

(c)

Figure 2. Photographs of (a) James Clerk Maxwell [11], (b) Albert Einstein [12], and (c) Erwin Schrödinger [13].

5 Cross-references

Cross-referencing is the act of referring to a numbered object, such as a figure, table, equation, or section. For example, you are currently reading Section 5 of this document, you probably just finished looking at Figure 2, and way back in Section 3, you saw Equations (1)-(7). As with citations, creating cross-references manually is a recipe for disaster. Imagine that you have just finished writing a report with over one hundred equations, when you decide that the last equation should have been first. If you were doing the cross-references manually, you would have to go through the entire document and change the number of each equation, not only for the equations themselves, but also everywhere you cross-referenced an equation!

Fortunately, LaTeX makes cross-references a breeze. Anything you want to cross-reference can be assigned a label using the `\label{}` command. The label is similar to the Bibtexkey of a reference: it is a unique identifier used to refer to the corresponding figure, table, equation, section, or whatever. You can then refer to the object using the `\eqref{}` command in the case of equations, and the `\ref{}` command in the case of everything else. For example, you might label Equation (1) `\label{eq:Newton2}`, and refer to it as `\eqref{eq:Newton2}`. Similarly, you might label Figure 1 `\label{fig:Newton}`, and refer to it as `Figure~\ref{fig:Newton}`. By assigning objects labels rather than specific numbers, LaTeX can automatically renumber all the objects when their order is changed, or when a new object is inserted in the middle. In the case of figures with multiple subfigures, you can label and subsequently cross-reference the entire figure as a whole—e.g., Figure 2—or each subfigure individually—e.g., Figure 2(b).

References

[1] The LaTeX Project. https://www.latex-project.org/.

[2] Texworks. http://www.tug.org/texworks/.

[3] Jabref. http://www.jabref.org/.

[4] Newton, I., 1687. *Philosophiae Naturalis Principia Mathematica*. Royal Society of London.

[5] Maxwell, J. C., 1865. "A dynamical theory of the electromagnetic field". *Philosophical Transactions of the Royal Society of London,* ***155***, pp. 459–512.

[6] Einstein, A., 1916. "Die Grundlage der allgemeinen Relativitätstheorie (The basis of the general theory of relativity)". *Annalen der Physik,* ***354***(7), pp. 769–822.

[7] Schrödinger, E., 1926. "Quantisierung als Eigenwertproblem (Quantization as eigenvalue problem)". *Annalen der Physik,* ***79***, pp. 361–376, 489–527, 734–756.

[8] Schrödinger, E., 1926. "Quantisierung als Eigenwertproblem (Quantization as eigenvalue problem)". *Annalen der Physik,* ***81***, p. 109.

[9] Detexify. http://detexify.kirelabs.org/classify.html.

[10] Isaac Newton. https://commons.wikimedia.org/wiki/File:GodfreyKneller-IsaacNewton-1689.jpg.

[11] James Clerk Maxwell. https://commons.wikimedia.org/wiki/File:James_clerk_maxwell.jpg.

[12] Albert Einstein. https://www.flickr.com/photos/alg0angelical/3307637331.

[13] Erwin Schrödinger. https://commons.wikimedia.org/wiki/File:Erwin_Schr%C3%B6dinger_(1933).jpg.

Appendix A. Common mathematical symbols

Table 2 shows some common mathematical symbols and their LaTeX syntax. Remember: if all else fails, use Detexify [9]!

Table 2. Some common mathematical symbols.

Description	Symbol(s)	LaTeX syntax
Greater than or equal to	$\geq$	`\geq`
Less than or equal to	$\leq$	`\leq`
Much greater than	$\gg$	`\gg`
Much less than	$\ll$	`\ll`
Identically equal to	$\equiv$	`\equiv`
Approximately equal to	$\approx$	`\approx`
Element of	$\in$	`\in`
Set union	$\bigcup$	`\bigcup`
Set intersection	$\bigcap$	`\bigcap`
Subset of	$\subset$	`\subset`
Similar to	$\sim$	`\sim`
Proportional to	$\propto$	`\propto`
Maps to	$\mapsto$	`\mapsto`
Right arrow	$\rightarrow$	`\rightarrow`
Implies	$\Rightarrow$	`\Rightarrow`
Square root	$\sqrt{x}$	`\sqrt{x}`
nth root	$\sqrt[n]{x}$	`\sqrt[n]{x}`
Infinity	∞	`\infty`
Summation	$\sum_{n=1}^{\infty}$	`\sum_{n=1}^{\infty}`
Product	$\prod_{n=1}^{\infty}$	`\prod_{n=1}^{\infty}`
Time derivative (Newton)	$\dot{x}$	`\dot{x}`
Partial differential	∂	`\partial`
Integral	$\int_{a}^{b}$	`\int_{a}^{b}`
Double integral	$\iint_{S}$	`\iint_{S}`
Triple integral	$\iiint_{V}$	`\iiint_{V}`
Closed line integral	$\oint_{\Gamma}$	`\oint_{\Gamma}`
Closed surface integral	$\oiint_{S}$	`\oiint_{S}`
Cartesian basis vectors	$\hat{\imath}, \hat{\jmath}, \hat{k}$	`\hat{\imath},\hat{\jmath},\hat{k}`
Gradient	∇	`\nabla`
Dot product	$\cdot$	`\cdot`
Cross product	$\times$	`\times`
Tensor product	$\otimes$	`\otimes`