

# Preparation of manuscripts for PHYS 422: Applied Solid State Physics using L<sup>A</sup>T<sub>E</sub>X

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This article explains and illustrates the use of L<sup>A</sup>T<sub>E</sub>X in preparing manuscripts for the final projects in the Fall 2018 semester's offering of PHYS 422: Applied Solid State Physics. While it is not a comprehensive reference, we hope it will suffice for the needs of most students. L<sup>A</sup>T<sub>E</sub>X has several features that make it my preferred document preparation method. These include automatic figure and equation numbering, simple reformatting capabilities, as well as excellent equation typesetting.

## INTRODUCTION

L<sup>A</sup>T<sub>E</sub>X is typesetting software that is widely used by mathematicians and physicists because it is so good at typesetting equations. It is also completely programmable, so it can be configured to produce documents with almost any desired formatting, and to automatically number equations, figures, endnotes, and so on.

To prepare your manuscripts for the final projects in PHYS 422, you should use the REV<sub>T</sub>E<sub>X</sub> 4.1 format for *Physical Review Letters* one column, as indicated in the `documentclass` line at the top of this article's source file.

This sample article is intended as a tutorial, template, and reference for students, illustrating most of the L<sup>A</sup>T<sub>E</sub>X and REV<sub>T</sub>E<sub>X</sub> features that authors will need. For a more comprehensive introduction to L<sup>A</sup>T<sub>E</sub>X, numerous books and online references are available.[1–3] Documentation for the REV<sub>T</sub>E<sub>X</sub> package can be found on the APS web site.[4] Or for quick short answers to things like “how to center a table?” googling your question can usually answer it quickly.

L<sup>A</sup>T<sub>E</sub>X is free software, available for Unix/Linux, Mac OS X, and Windows operating systems. For downloading and installation instructions, follow the links from the L<sup>A</sup>T<sub>E</sub>X web site.[1] It is most convenient[5] to install a “complete T<sub>E</sub>X distribution,” which will include L<sup>A</sup>T<sub>E</sub>X, the underlying T<sub>E</sub>X engine, macro packages such as REV<sub>T</sub>E<sub>X</sub>, a large collection of fonts, and GUI tools for editing and viewing your documents. To test your installation, try to process this sample article.

If you would rather not install latex you can consider using overleaf on the website [www.overleaf.com](http://www.overleaf.com). Overleaf also allows for easy file sharing among collaborators that may be useful for this project.

## ORDINARY TEXT AND PARAGRAPHS

To typeset a paragraph of ordinary text, just type the text in your source file like this. Put line breaks wherever you want, and don't worry about extra spaces between words, which L<sup>A</sup>T<sub>E</sub>X will ignore. You can almost always trust L<sup>A</sup>T<sub>E</sub>X to make your paragraphs look good, with neatly justified margins.

To start a new paragraph, just leave a blank line in your source file.

A few punctuation characters require special treatment in L<sup>A</sup>T<sub>E</sub>X. There are no “smart quotes,” so you need to use the left-quote key (at the top-left corner of the keyboard) for a left quote, and the ordinary apostrophe key (next to the semi-colon) for a right quote. Hit either key twice for double quotes, which are standard in American English. Don't use shift-apostrophe to make double quotes. Use single quotes when they're nested inside a double-quoted quotation. When a period or comma belongs at the end of a quotation, put it inside the quotes—even if it's not part of what you're quoting.[6]

Your fingers also need to distinguish between a hyphen (used for multi-word adjectives and for hyphenated names like Lennard-Jones), an en-dash (formed by typing two consecutive hyphens, and used for ranges of numbers like 1–100), and an em-dash (formed out of three consecutive hyphens and used as an attention-getting punctuation symbol—preferably not too often). While I will not be deducting credit for minor issues like this, it is good practice for formatting formal documents.

Some non-alphanumeric symbols like \$, &, and % have special meanings in a L<sup>A</sup>T<sub>E</sub>X source file, so if you want these symbols to appear in the output, you need to precede them with a backslash.

There are also special codes for generating the various accents that can appear in foreign-language words and names, such as Ampère and Schrödinger.[7]

You can switch to *italic*, **bold**, and **typewriter** fonts when necessary. Use curly braces to enclose the text that is to appear in the special font. In general, L<sup>A</sup>T<sub>E</sub>X uses curly braces to group characters together for some common transformation.

Notice that any word or symbol preceded by the backslash character is a special instruction to L<sup>A</sup>T<sub>E</sub>X, typically used to produce a special symbol or to modify the typeset output in some way. These instructions are also called *control sequences* or *macros*. After you've used L<sup>A</sup>T<sub>E</sub>X for a while, the little finger of your right hand will be really good at finding the backslash and curly-brace keys.

## MATH SYMBOLS

To type mathematical symbols and expressions within a paragraph, put them between \$ signs, which indicate *math mode*:  $ab + 2c/d = e - 3f$ . L<sup>A</sup>T<sub>E</sub>X ignores spaces in math mode, using its own algorithms to determine the right amount of space between symbols. Notice that an ordinary letter like  $x$ , when used in math mode, is automatically

typeset in italics. This is why you need to use math mode for all mathematical expressions (except plain numerals), even when they don't contain any special symbols. But don't use math mode to italicize ordinary *words*.

Besides ordinary letters and numerals and common arithmetic symbols, math mode provides a host of other characters that you can access via control sequences.[8] These include Greek letters like  $\pi$  and  $\Delta$  (note capitalization), symbols for operations and relations such as  $\cdot$ ,  $\times$ ,  $\pm$ ,  $\gg$ ,  $\leq$ ,  $\sim$ ,  $\approx$ ,  $\propto$ , and  $\rightarrow$ , and special symbols like  $\nabla$ ,  $\partial$ ,  $\infty$ , and  $\hbar$ . You can decorate symbols with dots ( $\dot{x}$  or  $\ddot{x}$ ), arrows ( $\vec{\mu}$ ), bars ( $\bar{x}$  or  $\overline{m}$ ), hats ( $\hat{x}$ ), tildes ( $\tilde{f}$  or  $\tilde{w}$ ), and radicals ( $\sqrt{\pi}$ ,  $\sqrt[2]{3}$ ). Parentheses and square brackets require no special keystrokes, but you can also make curly braces and angle brackets:  $\{\dots\}$ .

To make subscripts and superscripts, use the underscore and caret (circumflex) symbols on your keyboard:  $x^\mu$ ,  $g_{\mu\nu}$ ,  $\delta_j^i$ ,  $\epsilon^{ijk}$ . Notice that you need to put the subscript or superscript in curly braces if it's longer than one character (or one control sequence). You can even make nested subscripts and superscripts, as in  $e^{-x^2}$ . If a subscript consists of an entire word or word-like abbreviation, we usually put it in plain Roman type:  $x_{\text{max}}$ . If you need to put a subscript or superscript *before* a symbol, use an empty set of curly braces:  ${}^{235}_{92}\text{U}$ . (Notice the trick of using backslash-space put a space before the 92.)

To make boldface letters you use the `\mathbf` control sequence, as in  $\nabla \times \mathbf{E} = -\partial \mathbf{B} / \partial t$ . For bold Greek letters like  $\omega$ , you need to use `\boldsymbol` instead. You can also use calligraphic ( $\mathcal{E}$ ), Fraktur ( $\mathfrak{D}$ ), and blackboard bold ( $\mathbb{R}$ ) fonts, if you need them. If you'll be using a symbol in a special font repeatedly, you can save some keystrokes by defining an abbreviation for it; for example, the definition `\newcommand{\bE}{\mathbf{E}}` allows you to type simply `\bE` to get  $\mathbf{E}$ . Note: `newcommand` declarations like this can be used for things outside of mathmode as well, as is described in the preamble of this document.

Unit abbreviations, as in  $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$ , should be in the plain Roman font, not italics. You can access this font from math mode using `\mathrm`. For function names like  $\sin \theta$ ,  $\exp x$ , and  $\ln N!$ ,  $\text{\LaTeX}$  provides special control sequences, which you should use instead of `\mathrm` whenever possible because they work better with  $\text{\LaTeX}$ 's automatic spacing algorithms.

But  $\text{\LaTeX}$  doesn't always get the spacing right in mathematical formulas. In the previous paragraph we had to use the `\sim` symbol to manually insert a space between each number and its units. The `\sim` symbol actually represents an unbreakable space, where  $\text{\LaTeX}$  will never insert a line break. For occasional minor adjustments to the spacing in a  $\text{\LaTeX}$  expression, you can insert or remove a little space with `\,` and `\!`. Use these macros sparingly, because  $\text{\LaTeX}$ 's default spacing rules will provide more consistency within and among papers. The most common use of `\,` is in expressions like  $T dS - P dV$ .

## DISPLAYED EQUATIONS

When an equation is important and/or tall and/or complicated, you should display it on a line by itself, with a number. To do this, you put `\begin{equation}` before the equation and `\end{equation}` after it, as in

$$\int_0^\infty \frac{x^3}{e^x - 1} dx = 6 \sum_{k=1}^\infty \frac{1}{k^4} = 6 \left( \frac{\pi^4}{90} \right) = \frac{\pi^4}{15}. \quad (1)$$

This example also shows how to make the sum and integral symbols, big parentheses, and built-up fractions. (Avoid putting built-up fractions in a non-displayed equation, because there won't be enough vertical space in single-spaced paragraphs. Use the slashed form,  $x^3/(e^x - 1)$ , instead.)

If you want to refer to an equation elsewhere in your manuscript, you can give it a label. For example, in the equation

$$\frac{\Delta x}{\Delta t} \xrightarrow{\Delta t \rightarrow 0} \frac{dx}{dt} = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} \quad (2)$$

we've inserted `\label{deriv}` to label this equation `deriv`. [9] To refer to Eq. (2), we then type `\ref{deriv}`. [10] Notice that we are using the style convention of putting the equation number in parentheses when you refer to it, and to abbreviate "Eq." unless it's at the beginning of a sentence. Different journals have different conventions, the only requirement for this assignment is that you are consistent throughout your paper.

Some equations require more complicated layouts. In the equation

$$E_n = (n + \tfrac{1}{2})\hbar, \quad \text{where } n = 0, 1, 2, \dots, \quad (3)$$

we’ve used `\quad` to leave a wide space and `\textrm` to put “where” in plain Roman type. To create a matrix or column vector, as in

$$\begin{bmatrix} t' \\ x' \end{bmatrix} = \begin{pmatrix} \gamma & -\beta\gamma \\ -\beta\gamma & \gamma \end{pmatrix} \begin{bmatrix} t \\ x \end{bmatrix}, \quad (4)$$

you can use the `pmatrix` and/or `bmatrix` environment, for matrices delimited by parentheses and/or brackets. There’s also a plain `matrix` environment that omits the delimiters. In this and other examples of L<sup>A</sup>T<sub>E</sub>X tables and arrays, the `&` character serves as a “tab” to separate columns, while the `\\` control sequence marks the end of a row.

For a list of related equations, with nicely lined-up equals signs, use the `eqnarray` environment:

$$\oint \vec{B} \cdot d\vec{\ell} = -\frac{d\Phi_E}{dt}; \quad (5)$$

$$\oint \vec{E} \cdot d\vec{\ell} = \mu_0\epsilon_0 \frac{d\Phi_B}{dt} + \mu_0 I. \quad (6)$$

You can also use `eqnarray` to make a multi-line equation, for example,

$$\begin{aligned} \mathcal{Z} &= 1 + e^{-(\epsilon-\mu)/kT} + e^{-2(\epsilon-\mu)/kT} + \dots \\ &= 1 + e^{-(\epsilon-\mu)/kT} + (e^{-(\epsilon-\mu)/kT})^2 + \dots \\ &= \frac{1}{1 - e^{-(\epsilon-\mu)/kT}}. \end{aligned} \quad (7)$$

Here the first column of the second and third lines is empty. Note that you can use `\nonumber` within any line to suppress the generation of an equation number; just be sure that each multi-line equation has at least one number.

Another commonly used structure is the `cases` environment, as in

$$m(T) = \begin{cases} 0 & T > T_c, \\ (1 - [\sinh 2\beta J]^{-4})^{1/8} & T < T_c. \end{cases} \quad (8)$$

You should you put correct punctuation before and after every displayed equation, treating each equation as part of a correctly punctuated English sentence.[11] The preceding examples illustrate good equation punctuation.

## FIGURES

L<sup>A</sup>T<sub>E</sub>X can import figures via the `\includegraphics` macro. You should embed this in the `figure` environment, which can place the figure in various locations. This environment also lets you add a caption (required for this assignment and most journals) and an optional label for referring to the figure from elsewhere. See Fig. 1 for an example.

Most L<sup>A</sup>T<sub>E</sub>X implementations can import a variety of graphics formats. For graphs and line drawings you should use vector (i.e., resolution-independent) graphics saved in encapsulated PostScript (.eps) or portable document format (.pdf). Most good graphics software systems can save to one or both of these formats. Please don’t use a rasterized graphics format (such as .jpg or .png or .tiff) for graphs or line drawings.

For photographs and other images that are *inherently* made of pixels (that is, rasters or bitmaps), L<sup>A</sup>T<sub>E</sub>X can (usually) handle the .jpg and .png formats as well as .eps and .pdf. Figure 2 is a .jpg example. For final production, however, Some journals prefer that raster images be in .tiff format. Most L<sup>A</sup>T<sub>E</sub>X systems can’t import .tiff images, so we recommend using .png or .jpg with L<sup>A</sup>T<sub>E</sub>X for your initial submission, while saving a higher-quality .tiff version to submit as a separate file after your manuscript is conditionally accepted for publication.

## TABLES

Tables are somewhat similar to figures: You use the `table` environment to let them “float” to an appropriate location, and to automatically number them and format their captions. But whereas the content of a figure comes from an external file, the content of a table is typeset directly in L<sup>A</sup>T<sub>E</sub>X. For that you use the `tabular` environment, which uses `&` and `\\` for tabbing and ending rows, just like the `matrix` and `eqnarray` environments discussed in Section .

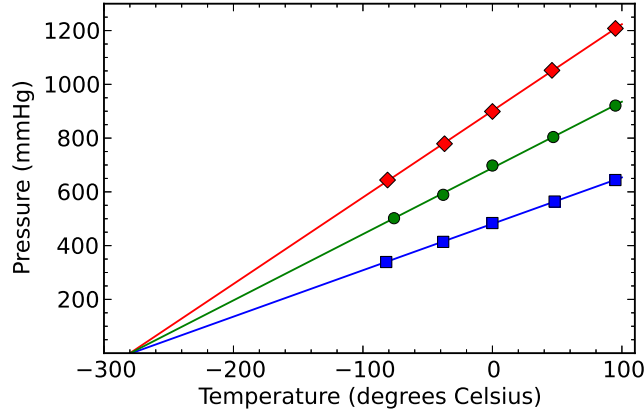


FIG. 1. Pressure as a function of temperature for a fixed volume of air. The three data sets are for three different amounts of air in the container. For an ideal gas, the pressure would go to zero at  $-273^{\circ}\text{C}$ . (Notice that this is a vector graphic, so it can be viewed at any scale without seeing pixels.)



FIG. 2. Three overlaid sequences of photos of the setting sun, taken near the December solstice (left), September equinox (center), and June solstice (right), all from the same location at  $41^{\circ}$  north latitude. The time interval between images in each sequence is approximately four minutes.

Table I shows a fairly simple example. Notice that the caption comes before the table itself, so it will appear above the table instead of below. The `ruledtabular` environment, which surrounds `tabular`, provides the double horizontal lines at the top and bottom, and stretches the table horizontally out to the margins. (This will look funny for tables intended to fill only one column of a final journal page, but there's no need to worry about such cosmetic details.)

TABLE I. Elementary bosons

Name	Symbol	Mass ( $\text{GeV}/c^2$ )	Spin	Discovered	Interacts with
Photon	$\gamma$	0	1	1905	Electrically charged particles
Gluons	$g$	0	1	1978	Strongly interacting particles (quarks and gluons)
Weak charged bosons	$W^{\pm}$	82	1	1983	Quarks, leptons, $W^{\pm}$ , $Z^0$ , $\gamma$
Weak neutral boson	$Z^0$	91	1	1983	Quarks, leptons, $W^{\pm}$ , $Z^0$
Higgs boson	$H$	126	0	2012	Massive particles (according to theory)

Every table is a little bit different, and many tables will require further tricks; see Refs. 2 and 3 for examples.

## SPECIAL FORMATS

### Block quotes

If a quoted passage is long or important, you can use the `quote` environment to typeset it as a block quote, as in this passage from The Feynman Lectures:[13]

A poet once said, “The whole universe is in a glass of wine.” We will probably never know in what sense he meant that, for poets do not write to be understood. But it is true that if we look at a glass of wine closely enough we see the entire universe.

### Numbered lists

To create a numbered list, use the `enumerate` environment and start each entry with the `\item` macro:

1. You can’t win.
2. You can’t even break even.
3. You can’t get out of the game.

### Unnumbered lists

For a bulleted list, just use `itemize` instead of `enumerate`:

- Across a resistor,  $\Delta V = \pm IR$ .
- Across a capacitor,  $\Delta V = \pm Q/C$ .
- Across an inductor,  $\Delta V = \pm L(dI/dt)$ .

### Literal text

For typesetting computer code, the `verbatim` environment reproduces every character verbatim, in a typewriter font:

```
u[t_] := NIntegrate[
  x^2 * Sqrt[x^2+t^-2] / (Exp[Sqrt[x^2+t^-2]] + 1), {x,0,Infinity}]
f[t_] := NIntegrate[
  x^2 * Log[1+ Exp[-Sqrt[x2+t^-2]]], {x,0,Infinity}]
Plot[((11Pi^4/90) / (u[t]+f[t]+(2Pi^4/45)))^(1/3), {t,0,3}]
```

There’s also a `\verb` macro for typesetting short snippets of verbatim text within a paragraph. To use this macro, pick any character that doesn’t appear within the verbatim text to use as a delimiter. Most of the examples in this article use `/` as a delimiter, but in `{a/b}` we’ve used `|` instead.

## ENDNOTES AND REFERENCES

This article has already cited quite a few endnotes, using the `\cite` macro. See the end of this article (and source file) for the endnotes themselves, which are in an environment called `thebibliography` and are created with the `\bibitem` macro. These macros require you to give each endnote a name. The notes will be numbered in the order in which the `\bibitem` entries appear, and for this assignment it is required that this order coincide with the order in

which the notes are first cited in the article. You can cite multiple endnotes in a single `\cite`, separating their names by commas. And you can cite each note as many times as you like.

Notice that in the Physical Review Letters style, the citation numbers appear in square parenthesis. In the Physical Review B style (replace `prl` with `prb` in the `documentclass`) the citation numbers appear as superscripts. Think carefully about the optimal placement of each citation, and try not to attach citations to math symbols where the numbers might be misinterpreted as exponents. Often there will be a punctuation symbol after the word where you attach the citation; you should then put the citation *after* the punctuation, not before.[6]

If you want to refer directly to Ref. 11 (or any other) in a sentence, you can do so with the `\onlinecite` macro.

Most endnotes consist of bibliographic citations.[14] For this assignment you will use the American Journal of Physics (AJP) citation style. Be sure to learn and use the AJP styles for citing books,[3] articles,[15] edited volumes,[16] and URLs.[1] For example, article titles are in double quotes, while book titles are in italics. Pay careful attention to all punctuation symbols in citations. Note that AJP requires that all article citations include titles as well as beginning and ending page numbers. Please use standard abbreviations, as listed in the AIP Style Manual,[17] for journal titles.

## CONCLUSION

I hope this article will help you prepare beautifully typeset manuscripts. Good typesetting requires considerable attention to detail, but this effort will pay off by making your manuscript easier and more enjoyable to read. Your colleagues, reviewers, and editors will be grateful for your effort.

Of course, we encourage you to put as much care into the *content* of your manuscript as you put into its form. The AIP Style Manual[17] is an indispensable reference on good physics writing, covering everything from planning and organization to standard spellings and abbreviations.

I look forward to receiving your final papers.

## Uninteresting stuff

Appendices are for material that is needed for completeness but not sufficiently interesting to include in the main body of the paper. Most articles don't need any appendices, but feel free to use them when appropriate. This sample article needs an appendix only to illustrate how to create an appendix.

We gratefully acknowledge the American Journal of Physics for providing a sample L<sup>A</sup>T<sub>E</sub>X document that was easy for me to edit and adapt for this purpose.

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- [1] L<sup>A</sup>T<sub>E</sub>X Project Web Site, <<http://www.latex-project.org/>>.
- [2] L<sup>A</sup>T<sub>E</sub>X (Wikibook), <<http://en.wikibooks.org/wiki/LaTeX/>>.
- [3] Helmut Kopka and Patrick W. Daly, *A Guide to L<sup>A</sup>T<sub>E</sub>X*, 4th edition (Addison-Wesley, Boston, 2004).
- [4] REV<sub>T</sub>E<sub>X</sub> 4 Home Page, <<https://authors.aps.org/revtex4/>>.
- [5] On the other hand, you can avoid the installation process entirely by using a cloud-based L<sup>A</sup>T<sub>E</sub>X processor such as Share-L<sup>A</sup>T<sub>E</sub>X, <<https://www.sharelatex.com/>>, or writeL<sup>A</sup>T<sub>E</sub>X, <<https://www.writelatex.com/>>.
- [6] In typography, aesthetics often takes precedence over logic.
- [7] Please don't try to handle foreign characters and accents with the `inputenc` and `fontenc` packages, which are incompatible with AJP's editing process.
- [8] See the Mathematics chapter of Ref. 2 for an excellent overview of math symbols and equations, with examples.
- [9] Thinking up a good label name takes a moment, but it's worth the trouble; we strongly advise against using labels like `eq2`, which become extremely confusing after you decide to add another equation before Eq. (2).
- [10] You need to process a file twice to get the counters correct.
- [11] N. David Mermin, "What's wrong with these equations?," *Phys. Today* **42** (10), 9–11 (1989).
- [12] American Journal of Physics Editor's Web Site, <<http://ajp.dickinson.edu>>.
- [13] Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics, Vol. 1* (Addison-Wesley, 1964), p. 3-10.
- [14] Many L<sup>A</sup>T<sub>E</sub>X users manage their bibliographic data with a tool called BIB<sub>T</sub>E<sub>X</sub>. Unfortunately, AJP cannot accept BIB<sub>T</sub>E<sub>X</sub> files; all bibliographic references must be incorporated into the manuscript file as shown here, at least when you send an editable file for production.

- [15] Freeman J. Dyson, “Feynman’s proof of the Maxwell equations,” *Am. J. Phys.* **58** (3), 209–211.
- [16] M. R. Flannery, “Elastic scattering,” in *Atomic, Molecular, and Optical Physics Handbook*, edited by G. W. F. Drake (AIP Press, New York, 1996), p. 520.
- [17] *AIP Style Manual*, 4th edition (American Institute of Physics, New York, 1990). Available online at <http://www.aip.org/pubservs/style/4thed/toc.html>. Although parts of it have been made out of date by advancing technology, most of this manual is still as useful as ever. Just be sure to follow AJP’s specific rules whenever they conflict with those in the manual.