Critical Temperature of YBCO and BSCCO Superconductors

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Abstract

This article explains and illustrates the use of LaTeX in preparing manuscripts for submission to the American Journal of Physics (AJP). While it is not a comprehensive reference, we hope it will suffice for the needs of most AJP authors.

I. INTRODUCTION

In 1911, Kamerlingh Onnes discovered superconductivity in mercury. Instead of a gradual decrease in the electrical resistance as the temperature decreased, he found a sudden loss of resistance when the temperature went below 4.2 K. The temperature at which the resistance disappears is called the critical temperature. In addition to having no resistance, superconductors also exhibit perfect diamagnetism, which means they exclude all magnetic field flux from their interior. This property, called the Meissner effect, was discovered in 1933.[1] A common demonstration of the Meissner effect is to place a a magnet on top of a superconductor above its critical temperature. When the superconductor is cooled to become superconducting, the magnet will start to levitate above the superconductor. This phenomenon can be used to make levitation trains. Superconductors are also used to create magnetic fields used in magnetic resonance imaging and in high energy physics to accelerate and control the path of particles.[2]

Superconductivity has been found to occur in elements, alloys, binary compounds, and other materials. Roughly 70 years after superconductivity was discovered, ceramic materials with critical temperatures above the liquid nitrogen temperature of 77 K were found.[3] These "high temperature" superconductors were made up of alternating layers of rare earth atoms and copper and oxygen atoms.[2] In our experiment, we look at two high temperature superconductors, $Yt_?Ba_?Cu_?O_?$ and $Bi_?Sr_?Ca_?Cu_?O_?$.

II. AIMS

1. To determine the critical temperature of YBCO and BSCCO.

III. PROCEDURE

The YBCO and BSCCO superconductors were obtained from Colorado Superconductor Inc. Each superconductor is contained in a brass casing with three pairs of leads. One pair was for attaching to the current source, another pair was used to measure voltage across the superconductor, and the last pair that of the thermocouple inside the casing. The thermocouple has a resistance that varies with temperature, so we can determine the temperature of superconductor by measuring the voltage across the thermocouple.

We used different methods to measure the critical temperature of the two superconductors. For the YBCO, we connected it to a source with an alternating current of ± 1 mA. The voltage across the YBCO sample, V_{YBCO}, and the voltage across the thermocouple, V_T were measured with two nanovoltmeters. We placed the supeconductor inside a styrofoam cup filled with sand. The sand reduces the rate at which the superconductor heats up, which allows us to gather more data points. We cooled the YBCO sample by pouring liquid nitrogen into the styrofoam cup. We monitored the thermocouple voltage to check when the temperature of the sample settled to a minimum.

IV. RESULTS AND ANALYSIS

V. DISCUSSION

VI. CONCLUSION

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 LaTeX will ignore. You can almost always trust LaTeX 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 LaTeX. 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.[9]

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).

Some non-alphanumeric symbols like \$, &, and % have special meanings in a LaTeX 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.[10]

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, LaTeX 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 LaTeX, 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 LaTeX for a while, the little finger of your right hand will be really good at finding the backslash and curly-brace keys.

To type mathematical symbols and expressions within a paragraph, put them between $ signs, which indicate *math mode*: $ab + 2c/d = e - 3f$. LaTeX 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.[11] These include Greek letters like π and Δ (note capitalization), symbols for operations and relations such as $\cdot$, $\times$, $\pm$, $\gg$, $\leq$, $\sim$, $\approx$, $\propto$, and $\rightarrow$, and special symbols like ∇, ∂, ∞, 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 $\widetilde{w}$), 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: $\{\langle \cdots \rangle\}$.

To make subscripts and superscripts, use the underscore and caret (circumflex) symbols on your keyboard: x^{μ}, $g_{\mu\nu}$, δ^{i}_{j}, ϵ^{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_{max}. If you need to put a subscript or superscript *before* a symbol, use an empty set of curly braces: ${}^{235}_{92}\mathrm{U}$. (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 $\boldsymbol{\omega}$, 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 $\mathbf{E}$.

Unit abbreviations, as in $1\ \mathrm{eV} = 1.6 \times 10^{-19}\ \mathrm{J}$, 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 $\ln N!$, LaTeX provides special control sequences, which you should use instead of `\mathrm` whenever possible because they work better with LaTeX's automatic spacing algorithms.

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

VII. 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

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

This example also shows how to make the sum and integral symbols, big parentheses, and built-up fractions. (Don't put built-up fractions in a non-displayed equation, because there won't be enough vertical space in AJP's final, 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

$$\frac{\Delta x}{\Delta t} \underset{\Delta t \to 0}{\longrightarrow} \frac{dx}{dt} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \tag{2}$$

we've inserted `\label{deriv}` to label this equation `deriv`.[12] To refer to Eq. (2), we then type `\ref{deriv}`.[13] Notice that AJP's style conventions also require you to put the equation number in parentheses when you refer to it, and to abbreviate "Eq." unless it's at the beginning of a sentence.

Some equations require more complicated layouts. In the equation

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

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

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

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 LaTeX 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:

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

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

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

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

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

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

At AJP we require that you put correct punctuation before and after every displayed equation, treating each equation as part of a correctly punctuated English sentence.[14] The preceding examples illustrate good equation punctuation.

VIII. FIGURES

LaTeX can import figures via the `\includegraphics` macro. For AJP, you should embed this in the `figure` environment, which can place the figure in various locations. This environment also lets you add a caption (which AJP requires) and an optional label for referring to the figure from elsewhere. See Fig. 1 for an example.

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°C. (Notice that this is a vector graphic, so it can be viewed at any scale without seeing pixels.)

Most LaTeX 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.

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° north latitude. The time interval between images in each sequence is approximately four minutes.

For photographs and other images that are *inherently* made of pixels (that is, rasters or bitmaps), LaTeX can (usually) handle the .jpg and .png formats as well as .eps and .pdf. Figure 2 is a .jpg example. For final production, however, AJP prefers that raster images be

in .tiff format. Most LaTeX systems can't import .tiff images, so we recommend using .png or .jpg with LaTeX 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.

Please refer to the AJP editor's web site[15] for more details on AJP's requirements for figure preparation.

IX. 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 LaTeX. 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 VII.

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 (GeV/c^2)	Spin	Discovered	Interacts with
Photon	γ	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, γ
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. 5

and 6 for examples. Note that the AJP style does not ordinarily use lines to separate rows and columns in the body of a table.

X. SPECIAL FORMATS

A. 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:[16]

> 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.

B. 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.

C. 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, $\Delta V = \pm L(dI/dt)$.

D. 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.

XI. 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 AJP requires 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 AJP (and Physical Review B) style, 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.[9]

If you want to refer directly to Ref. 14 (or any other) in a sentence, you can do so with the `\onlinecite` macro.

Most endnotes consist of bibliographic citations.[17] Be sure to learn and use the AJP styles for citing books,[6] articles,[18] edited volumes,[19] and URLs.[4] 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,[20] for journal titles.

XII. CONCLUSION

We hope this article will help you prepare beautifully typeset manuscripts for the American Journal of Physics. 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[20] is an indispensable reference on good physics writing, covering everything from planning and organization to standard spellings and abbreviations.

Most important of all, please familiarize yourself with the AJP Statement of Editorial Policy,[15] which describes the types of manuscripts that AJP publishes and the audience for which AJP authors are expected to write. You wouldn't want to put all that care into preparing a manuscript for AJP, only to find that AJP is the wrong journal for your manuscript.

We look forward to receiving your submission to AJP.

Appendix: 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.

ACKNOWLEDGMENTS

We gratefully acknowledge Harvey Gould and Jan Tobochnik, who created an earlier AJP LaTeX sample article that inspired this one. This work was supported by the American Association of Physics Teachers.

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[1] Charles Poole, Horacio Farach, and Richard Creswick, *Superconductivity* (Academic Press, 2007).

[2] Ajay Kumar Saxena, *High-Temperature Superconductors* (Springer Berlin Heidelberg, 2010).

[3] Experiments in Modern Physics. Adrian Constantin Melissinos and Jim Napolitano. Gulf Professional Publishing, 2003

[4] LaTeX Project Web Site, `<http://www.latex-project.org/>`.

[5] *LaTeX* (Wikibook), `<http://en.wikibooks.org/wiki/LaTeX/>`.

[6] Helmut Kopka and Patrick W. Daly, *A Guide to LaTeX*, 4th edition (Addison-Wesley, Boston, 2004).

[7] REVTeX 4 Home Page, `<https://authors.aps.org/revtex4/>`.

[8] On the other hand, you can avoid the installation process entirely by using a cloud-based LaTeX processor such as ShareLaTeX, `<https://www.sharelatex.com/>`, or writeLaTeX, `<https://www.writelatex.com/>`.

[9] In typography, aesthetics often takes precedence over logic.

[10] Please don't try to handle foreign characters and accents with the `inputenc` and `fontenc` packages, which are incompatible with AJP's editing process.

[11] See the Mathematics chapter of Ref. 5 for an excellent overview of math symbols and equations, with examples.

[12] 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).

[13] You need to process a file twice to get the counters correct.

[14] N. David Mermin, "What's wrong with these equations?," Phys. Today **42** (10), 9–11 (1989).

[15] American Journal of Physics Editor's Web Site, `<http://ajp.dickinson.edu>`.

[16] Richard P. Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics, Vol. 1* (Addison-Wesley, 1964), p. 3-10.

[17] Many LaTeX users manage their bibliographic data with a tool called BIBTeX. Unfortunately, AJP cannot accept BIBTeX files; all bibliographic references must be incorporated into the manuscript file as shown here, at least when you send an editable file for production.

[18] Freeman J. Dyson, "Feynman's proof of the Maxwell equations," Am. J. Phys. **58** (3), 209–211.

[19] 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.

[20] *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.