Measuring the Verdet Constant in XXXXX

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(Dated: October 4, 2014)

Abstract

I. INTRODUCTION

II. METHODS

Our experimental setup was based off the TeachSpin teaching manual. We used a TeachSpin XXXX consisting of a diode laser, a solenoid, a polarizing lens and photodetector. Our power source was a XXXXX which we used on current control throughout our experiment. We connected the two 3 volt ?? terminals in parallel so that we could obtain a total current of 3 amps through the solenoid. We used a Keithley XXXX function generator to modulate the laser at at frequency of XXXXX. The signal from the photodiode was run through a preamp and a bandpass filter and a lock-in detector. We used lock-in detector to stabilize our measurements and filter out ambient light from the room along with other forms of systematic error.

III. RESULTS

We performed the experiemnt to measure the verdet constant of our material in two different ways, and so obtained two different sets of data. From the measurement of light intensity due to changing polarization filter angle in a constant magnetic field, for currents of 0A, 1A, 2A, and 3A, we obtained the results shown in Figure 1.

From the measurements of changing magnetic field, with a constant polarization filter angle, for currents from -3A to 3A in steps of 0.5A, we obtained the results shown in Table I.

IV. ANALYSIS

V. MATH SYMBOLS

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

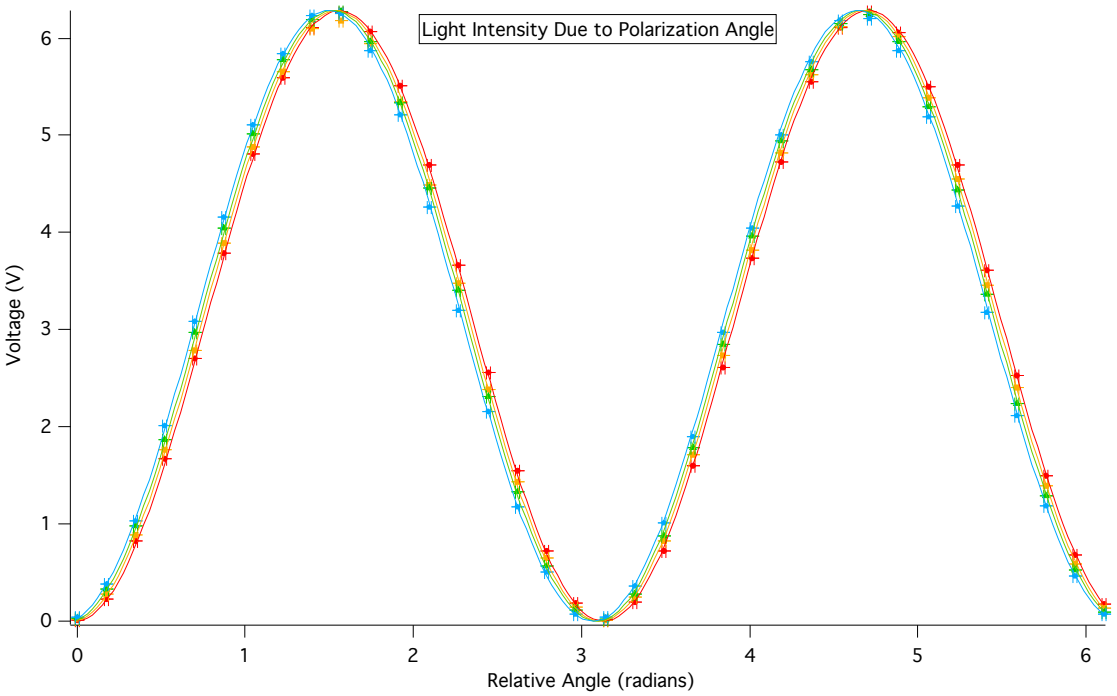

FIG. 1. Photo-detector voltage (proportional to light intensity) plotted against relative angle (the angle between the filter and the lasers polarization) from 0 to 2pi radians. The red points are the measurements taken without a magnetic field, the orange points were taken with 1A of current passing through the solenoid, the green points with the current at 2A, and the blue points at 3A. The curve fits are the function $V = A\cos^2(\theta + C)A$, with A held constant at 6.2845 V (obtained from the first curve fit), and C calculated by the curve fit.

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 π and Δ (note capitalization), symbols for operations and relations such as $\cdot$, $\times$, $\pm$, $\gg$, $\leq$, $\sim$, $\approx$, $\propto$, and $\to$, 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

TABLE I. Voltage readings from the photodetector for various currents applied to the solenoid.

Current (A)	Voltage (V)	Error Voltage (V)
-3	2.822	1.30E-10
-2.5	2.887	5.47E-10
-2	2.951	3.72E-10
-1.5	3.016	3.78E-11
-1	3.082	8.98E-10
-0.5	3.145	9.03E-10
0	3.211	1.18E-09
0.5	3.272	1.16E-10
1	3.338	2.05E-09
1.5	3.404	2.13E-09
2	3.468	6.96E-10
2.5	3.534	1.12E-09
3	3.599	1.05E-09

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

TABLE II. The fields due to the currents in table I applied to our solenoid, with the resulting voltage measured by the photodetector.

Magnetic Field * Length (mT*cm)	Error B*L (mT*cm)	Voltage (V)	Error Voltage (V)
-323	12	2.822	1.30E-10
-269	10	2.887	5.47E-10
-215	8	2.951	3.72E-10
-161	6	3.016	3.78E-11
-108	4	3.082	8.98E-10
-54	2	3.145	9.03E-10
0	0	3.211	1.18E-09
54	2	3.272	1.16E-10
108	4	3.338	2.05E-09
161	6	3.404	2.13E-09
215	8	3.468	6.96E-10
269	10	3.534	1.12E-09
323	12	3.599	1.05E-09

TABLE III. C values taken from the curve fits to Figure 1

Current (A)	C value from curve fit (rad)	Error C value (rad)
0	0.0088553	0.001
1	0.030849	0.0014
2	0.049599	0.0013
3	0.072754	0.0015

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

TABLE IV. Calculated phase shifts for the changing angle experiment, with the magnetic fields calculated from the applied currents.

Phase Shift (rad)	Error Phase Shift (rad)	Magnetic Field*Length (mT*cm)	Error Magnetic Field*Length (mT*c
0	0.002	0	0
0.022	0.0024	108	4
0.0407	0.0023	215	8
0.0639	0.0025	323	12

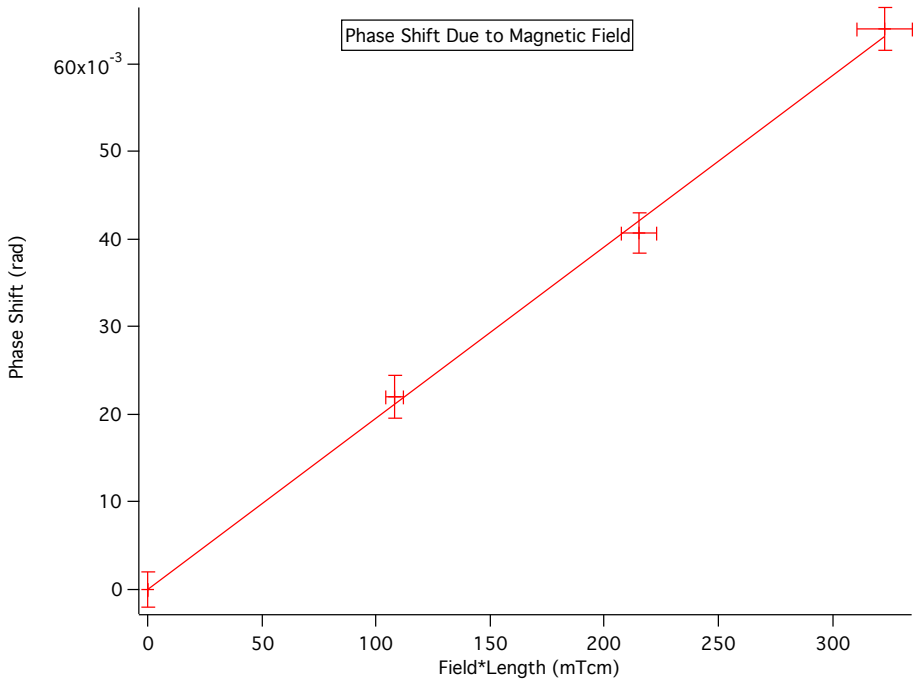

FIG. 2. A plot of Table IV, applied magnetic field (times length of the refracting material) versus the resulting phase shift in the polarization of the laser beam. The slope of a linear curve fit of this plot gives a value for the verdet constant of the material.

LaTeX's default spacing rules will provide more consistency within and among AJP articles. The most common use of `\,` is in expressions like $T\,dS - P\,dV$.

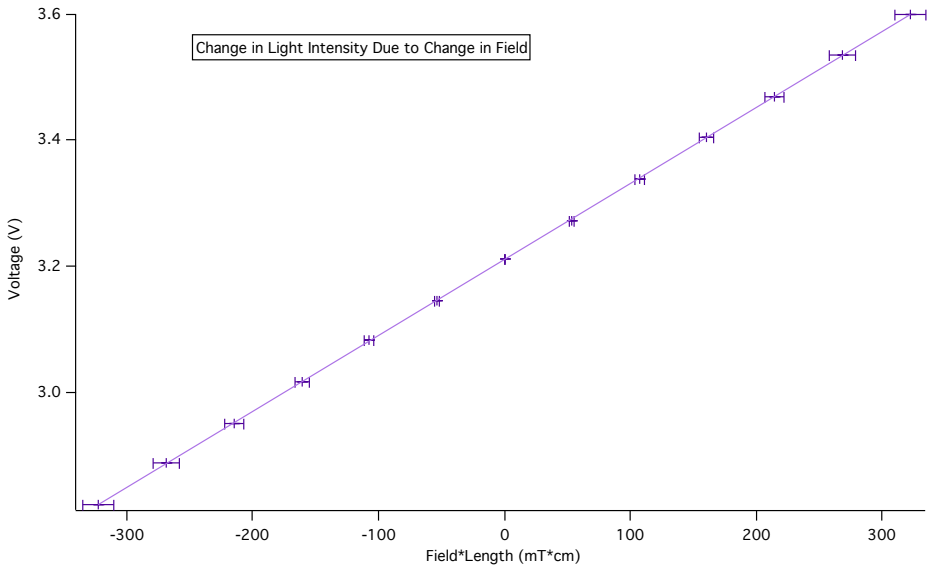

FIG. 3. A plot of Table II, the applied magnetic field (times the length of the refracting material) versus the voltage measured by the photodetector for that field. The slope of a linear curve fit to this plot can be used to calculate the verdet constant of the material.

VI. 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`.[9] To refer to Eq. (2), we then type `\ref{deriv}`.[10] 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.[11] The preceding examples illustrate good equation punctuation.

VII. 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. 4 for an example.

FIG. 4. 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.

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 5 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[12] for more details on AJP's requirements for figure preparation.

VIII. 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

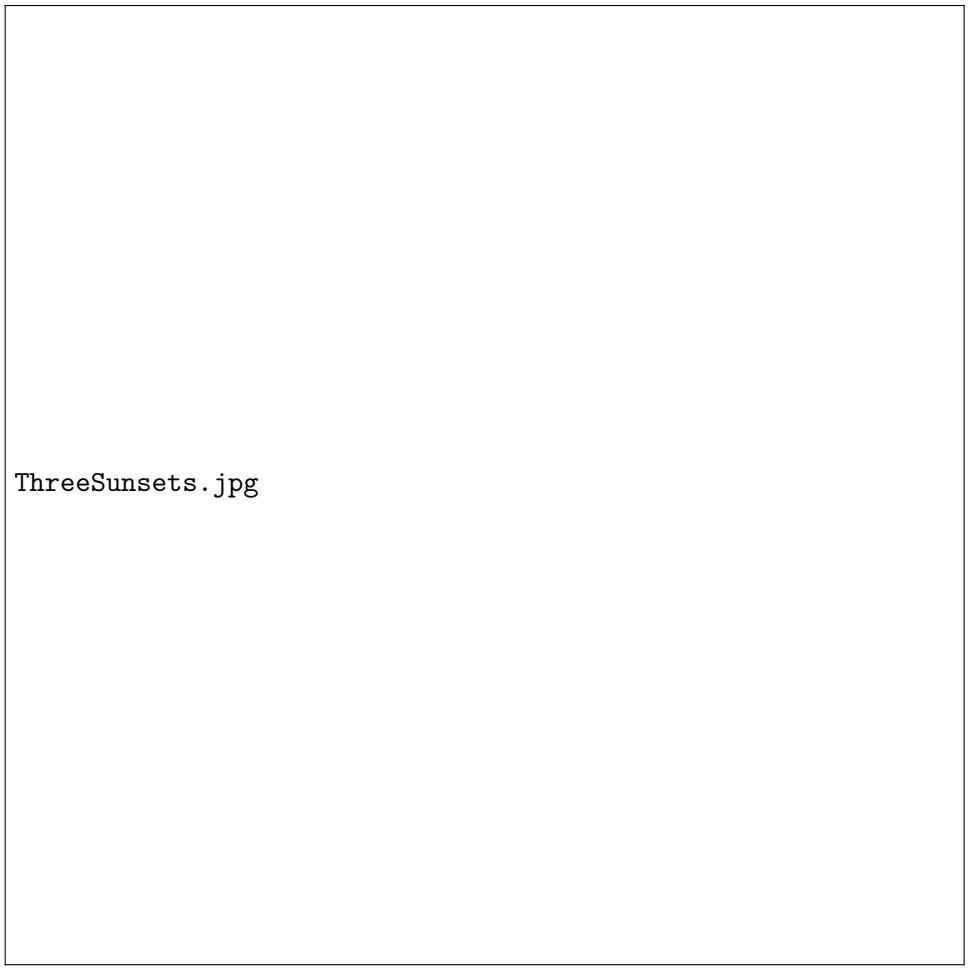

FIG. 5. Three overlaid sequences of photos of the setting sun, taken near the December solstice (left), September equinox (center), and June solstice (right), all from the same location at 41° north latitude. The time interval between images in each sequence is approximately four minutes.

discussed in Section VI.

Table V 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.)

Every table is a little bit different, and many tables will require further tricks; see Refs. 2 and 3 for examples. Note that the AJP style does not ordinarily use lines to separate rows and columns in the body of a table.

TABLE V. 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)

IX. 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:[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.

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.

X. 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.[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] 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.

XI. 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[17] 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,[12] 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 LaTeX Project Web Site, `<http://www.latex-project.org/>`.

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

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

4 REVTeX 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 LaTeX processor such as ShareLaTeX, `<https://www.sharelatex.com/>`, or writeLaTeX, `<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 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.

[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.