

A Minimal Example for Junior Lab Reports Using L^AT_EX

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This paper is a minimal example of a written summary for use by MIT Physics Junior Lab students. It uses L^AT_EX (pronounced *lay-tek* or *lah-tek*, but never *lay-teks*) and the REV_TE_X macro package from the American Physical Society to produce a professional quality document. A more extensive example template which demonstrates many more common L^AT_EX “tricks” is available from the Junior Lab web pages, but the present document may be easier for first time L^AT_EX users. In regards to content, the individual summary you hand in should show evidence of your own mastery of the entire experiment. It should also possess a neat appearance with concise and correct English. The abstract of the paper should briefly mention the motivation, the method, the quantitative result, and the result’s uncertainties. The length of the paper should be no more than two double-sided pages including all figures.

An important part of your education as a physicist is learning to use standard tools such as L^AT_EX which enable you to share your work with others in a widely accepted professional style. Spending a few hours studying and altering this document will allow you to develop sufficient mastery of L^AT_EX to easily generate all manner of technical documents. Specific instructions for compiling L^AT_EX documents on various operating systems are contained in the Appendices.

This is the introductory section of the paper. Your introduction should *succinctly* report the motivation, purpose, and relevant background to the experiment in way that is accessible to your audience. For Junior Lab, the appropriate audience is a stereotypical Junior Lab student who has background knowledge and experience similar to your own, but is totally unfamiliar with your experiment.

I. PROBLEM AND RELEVANT THEORY

The body of the summary should include a brief discussion of the motivation or theoretical issues addressed by the experiment. This should be done at a level such that another 8.13 student could follow your development.

The report should be type-written in a form that would be suitable for submission as a manuscript for publication in a professional journal such as Physical Review Letters. One helpful resource is the *APS Physical Review Style and Notation Guide* [1]. Another is the *AIP Style Manual* [2]. Figures (created as PDF or PNG files) should be inserted into the text in their natural positions.

If you are individually writing up results you obtained with a partner, use “we” and “I” appropriately. Note the following admonition from the *AIP Style Manual* [2, Section III.A.9]:

The old taboo against using the first person in formal prose has long been deplored by

the best authorities and ignored by some of the best writers. “We” may be used naturally by two or more authors in referring to themselves; “we” may also be used to refer to a single author and the author’s associates. A single author should also use “we” in the common construction that politely includes the reader: “We have already seen. . . .” But never use “we” as a mere substitute for “I,” as in, for example, “In our opinion. . . ,” which attempts modesty and achieves the reverse; either write “my” or resort to a genuinely impersonal construction.

Use the past tense for your procedure and analysis, the past perfect for preparation and the present for emphasis or conclusions. For example, “Since we had previously measured constructive and destructive interference, we concluded that electrons are waves.”

Some further tips:

- Be sure your figures have comprehensible captions.
- Make a complete estimate of your errors — not just statistical — even if it is crude.
- Trace the origin of formulae you use (*e.g.* Moseley’s law) to well known physics (in this case, to the Bohr atom). Do *not* derive: just indicate what new assumptions are needed.

Lastly: Remember to *proofread your paper for spelling and grammar mistakes*. Few things are as offensive to a reviewer as careless writing. Such mistakes will count against you!

One of the great powers of L^AT_EX is its ability to typeset all manner of mathematical expressions. While it does take a short while to get used to the syntax, it will soon become second nature. Numbered, single-line equations are the most common type of equation in Junior Lab papers. For example,

$$\chi_+(p) = x^2 + \frac{\partial y}{\partial z} \times \sqrt{\langle \psi | \alpha^\dagger | \phi \rangle} - \sin \theta. \quad (1)$$

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Be sure there is *no empty line* in your L^AT_EX source code between `\end{equation}` and the following body text unless you want a new paragraph to start there (and be indented). Also, remember to punctuate your equations according to their usage as parts of sentences.

Mathematics can also be placed directly in the text using `$` delimiters: the energy E is related to the mass m via $E = mc^2$, where c is the speed of light. As in the previous sentence, you should use this construction not just for whole equations in running text, but also for referring to individual variables by name: otherwise the variables will be set in different typefaces when appearing in text versus equations.

Infrequently, you may wish to typeset long equations which span more than one line of a two-column page. A good solution is to split up the equation into multiple lines and label all lines with a single equation number, as in Equation (2). See the L^AT_EX source to see how this is done using the `multiline` environment.

$$\sum |M_g^{\text{viol}}|^2 = g_S^{2n-4} (Q^2)^{n-2} (N^2 - 1) \times \left(\sum_{i < j} \right) \sum_{\text{perm}} \frac{1}{S_{12}} \frac{1}{S_{12}} \sum_{\tau} c_{\tau}^f. \quad (2)$$

Since L^AT_EX does not know mathematical grammar, you have to tell it the appropriate place to split the input using the `\\` sequence.

II. EXPERIMENTAL SKETCH AND SALIENT DETAILS

Here is an example first sentence of an experimental section: The experimental apparatus consists of a specially prepared chemical sample containing $^{13}\text{CHCl}_3$, an NMR spectrometer, and a control computer, as shown in Fig. 1.

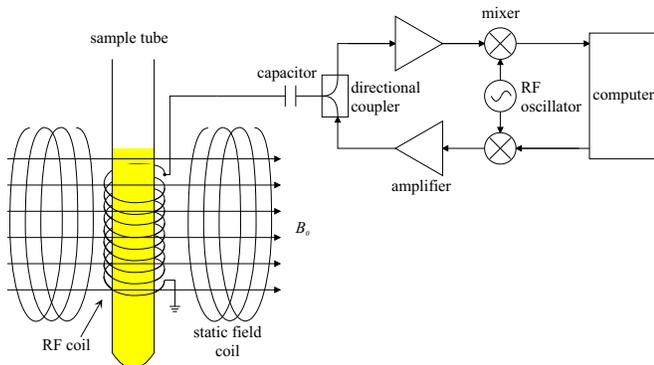


FIG. 1. This is a schematic of the main apparatus. Use the caption space to elaborate on specific issues, complications, or operating procedures. This is especially valuable given the limited amount of space in the main body of text. Adapted from [3, 4].

This section describes the main components of the apparatus and procedures used. It always makes reference to a figure(s) which contains a block diagram or schematic of the apparatus and perhaps includes the most important signal processing steps. The figure should be referenced as early as possible in this section with the placement of the figure as close to the descriptive text as is possible. It is usually necessary to place additional information within the figures themselves or in their captions for which there is no room in the main body of text. This will help you stay within the four page limit.

III. DATA PRESENTATION AND ERROR ANALYSIS

Graphics, such as Fig. 2, should be well thought out and crafted to maximize their information content while retaining clarity of expression.

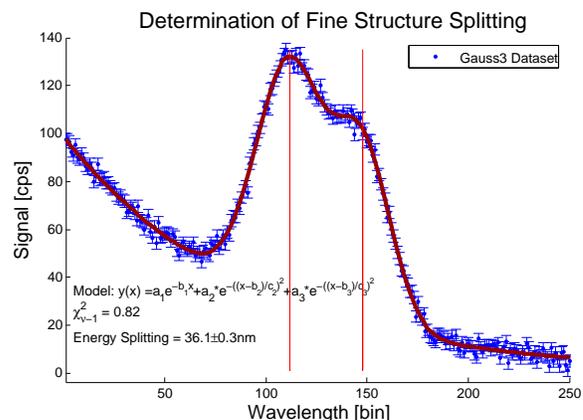


FIG. 2. Sample figure describing a set of data, fit procedures and results, created using the Junior Lab MATLAB template script at <http://web.mit.edu/8.13/matlab/fittemplate11.m>. Use the caption space to provide more details about the fitting procedure, results, or implications if you do not have sufficient room in the main body of text.

All papers should have at least one graphic showing an assemblage of raw data. Often these primary data are analyzed in a specific way that needs to be clearly communicated to the reader as another graphic. For example, a graphic demonstrating a typical analyzed result, functional model, and reduced χ^2 is shown in Fig. 2. Finally, there should be one graphic which summarizes the experimental data, and which conveys the primary finding(s) of the laboratory exercise. You may find that you need more, but these three should be a minimum. Finally, it can be useful in *some* circumstances to have a table of results, see Table I.

If you reuse graphics from your paper in oral presentation slides, make sure to increase the size of all the fonts so that they remain legible from 20 feet away!

TABLE I. An example table. Always use a preceding zero in the data you record in tables. *Always display units!* Inspect the L^AT_EX source for this table to see exactly how it is done.

	r_c (Å)	r_0 (Å)	κr_0		r_c (Å)	r_0 (Å)	κr_0
Cu	0.800	14.10	2.550	Sn	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb	0.450	1.930	3.760
Tl	0.480	18.90	3.550				

If circumstances in an experiment are such that you cannot get your own data (*e.g.* broken equipment, bad weather), you may use another students' data *provided you acknowledge it and have received your instructor's explicit permission.*

IV. CONCLUSIONS

The conclusion section is *not* simply a summary of your measurement results, but rather a commentary on the

scientific meaning of those results. Remember to report your results with appropriate significant digits, units, and uncertainties, *e.g.* $Q = (2.12 \pm 0.06) \text{ kg}\cdot\text{s}^{-1}$. It is often useful to express the quality of your result by measuring how many standard deviations it lies from expected values. Do *not* apologize or make excuses for your data.

Bibliographic entries are made within a separate `.bib` file which gets attached during process of building a final PDF document. See this document's `sample-paper.bib` file for details on several types of bibliographic entries and their required and optional fields.

ACKNOWLEDGMENTS

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- [1] A. Waldron, P. Judd, and V. Miller, *Physical Review Style and Notation Guide*, American Physical Society (2011).
 - [2] *AIP Style Manual*, American Institute of Physics, 4th ed. (1990).
 - [3] A. Melissinos, *Experiments in Modern Physics* (Academic Press, 1966).
 - [4] A. Melissinos and J. Napolitano, "Experiments in modern physics," (Academic Press, 2003) Chap. 5, pp. 179–184, 2nd ed.

Appendix A: L^AT_EX on Windows

For students who would like to use a Windows platform, MiK_TE_X (pronounced *mik-tek*) is a freely available implementation of T_EX and related programs available from www.miktex.org. Note that MiK_TE_X itself runs from a command line prompt and is not terribly convenient unless you are comfortable with the Windows shell. Luckily, MiK_TE_X comes packaged with the T_EXWORKS editing environment as a front end to L^AT_EX. Many beginners find T_EXWORKS easier and more intuitive to use than the alternative of a generic text editor and command line compilation. Advanced users may prefer a more powerful editor like EMACS or VI instead of a L^AT_EX-specific editor like T_EXWORKS.

Note that due to some “bad” distributions of L^AT_EX floating around the internet, some Windows users may need to update their L^AT_EX installation to the latest version of REV_TE_X-4.1 and the required natbib package. Alternatively, they can use the older REV_TE_X-4 by changing the `\documentclass` declaration at the beginning of the source file. You will know if you need to do this if you attempt to compile this sample document and receive errors about bad bibliography entries.

Once you have installed the above software, you will need to download the source files listed in the next section and put them on your Windows machine in order to “rebuild” this document from scratch.

Appendix B: L^AT_EX on Athena

For students wishing to utilize MIT’s Athena environment, the process to create your documents is quite simple. You can use the following commands verbatim or tweak them to suit your own organizational system.

In your home directory on Athena, create a convenient directory structure for all of your Junior Lab work by typing:

```
> mkdir ~/8.13
> mkdir ~/8.13/papers
> mkdir ~/8.13/papers/simple
> cd ~/8.13/papers/simple
```

Once this (or similar) directory structure has been created, copy all of the files needed to compile the template from the Junior Lab locker into your own Athena account by typing:

```
> cp /mit/8.13/www/Samplepaper/simple-zipped/* .
```

The final period above places the copied files into the current directory so make sure you are in the correct directory! You can see where you are by typing:

```
> pwd
```

The following files should now be in your current directory:

```
simple-paper.tex
simple-paper.bib
simple-paper.pdf
sample-fig1.pdf
sample-fig2.pdf
```

Additional files may also have been copied but do not worry: these get regenerated when you build your PDF document.

Now build the file (omitting the `.tex` suffix in the following steps):

```
> pdflatex simple-paper
> bibtex simple-paper
> pdflatex simple-paper
> pdflatex simple-paper
```

The repeated calls to `pdflatex` are necessary to resolve any nested references in the final PDF file. The `bibtex` call reads in the bibliography file `simple-paper.bib` allowing citation references to be resolved.

Remember to “ispell -t filename.tex” to perform a L^AT_EX-safe spell check before handing in your paper!

Appendix C: Graphics Utilities

Students should become proficient with a simple vector based drawing program such as INKSCAPE. Every written summary should include one or two simple schematics, based on your initial hand sketches from your lab notebook

It is easy to convert images from one format to another, *e.g.* a scanned JPEG or bitmap image into a PDF file for inclusion into a written summary. A useful utility, available on some Unix machines, is IMCONVERT. Typing `imconvert` without any arguments will show you the accepted file types. Other useful conversion utilities include PS2PDF, EPS2PDF, and a variety of similar programs.

MATLAB is perhaps the most common tool used by Junior Lab students for data analysis and representation. MATLAB figures can incorporate L^AT_EX symbols in their titles, axes labels, and text labels. Figures can be saved directly into PDF or PNG format, obviating the need for any further format conversion.