

# 6: Scientific Paper

My freedom will be so much the greater and more meaningful the more narrowly I limit my field of action and the more I surround myself with obstacles. Whatever diminishes constraint, diminishes strength. The more constraints one imposes, the more one frees one's self of the chains that shackle the spirit. . . And the arbitrariness of the constraint serves only to obtain precision of execution

Igor Stravinsky

*Poetics of Music in the Form of Six Lessons* (1947) p.65

The devil is in the details

Anonymous

## Paper Topics:

Presentation of a lab project as a scientific paper is the final component of this course. I will be assigning you a topic; feel free to drop me email with a list of your preferences! (First come, first served. Choose a topic ASAP and avoid the crunch at finals!) Topics:

1. Bubble Chamber:  $m_\mu$
2. Bubble Chamber:  $m_\pi$
3. Photometry:  $T_B, T_R$
4. Thermionic Emission: Stefan-Boltzmann Law
5. Thermionic Emission: Richardson-Dushman Law
6. Thermionic Emission: Child-Langmuir Law
7. Langmuir Probe:  $T_e$
8. Langmuir Probe:  $n_e$
9. Langmuir Probe:  $V_f, V_p$

## Paper Basics:

- sections:** Title, Author(s) with affiliation, Abstract, Introduction, main body (traditionally: Methods & Materials, Theory, Results, Discussion), Conclusions, Acknowledgments, References. You are encouraged to use specific (rather than the traditional generic) section titles in your main body.
- first steps:** Assemble your figures. Your figures should convey your main points: they should entice the expected audience to read a few words of the paper. Expect that the reader will not read your paper: if at all possible, the figure captions should explain the figure to a skimming reader. Your figures must be legible when reduced to a few inches; larger-than-normal fonts are usually required. Typically you will need to use a drawing program to make a block diagram of your apparatus.
- Introduction:** The Introduction explains why this experiment should be of interest to the reader. Cite and explain what other workers have discovered about the topic. (See these guys care about this stuff, so you should too!) Connect the experiment in the ongoing parade of science. Not uncommonly the experiment is of interest to you only because your Boss told you to do it. If so your Boss may be able to transmit his enthusiasm for the project to you (or maybe he has some boilerplate you can recycle). Beware: the Introduction is the easiest place to plagiarize (because it's stuff all those people you cite also wrote about). For me the Introduction is always the most interesting section to read: it starts with basic-level knowledge and brings me up-to-speed on a topic that I probably didn't know much about to start.
- Methods:** Discussion of methods is often the hardest part to write. You know the thousand details the experiment required; now you must reduce that to a few paragraphs. If you're lucky you can cite another paper for many details, but in any case you must inform the reader about what and how measurements were made; and how those meter readings related to deeper physical concepts. You don't need to tell the reader everything, but you must say enough. In this lab paper you should report how you estimated uncertainties. Since these experiments often hinge on systematic error, you will also discuss errors in sections discussing results. In most published papers it is simply assumed that the errors have been properly estimated. Professionally the consequences for even accidental mis-estimation of errors can be life-changing (non-tenure).
- Abstract:** While the Abstract is the first section of the paper, it is the last thing you should write. The Abstract summarizes the significant items in the paper including the results and conclusions. The Abstract should make sense isolated from the paper: do not refer to equations or figures in the paper. (In fact collections of Abstracts are commonly separately published without the corresponding papers and are often the text digested by search engines.) The Abstract should be short: perhaps a sentence for every section

of the paper. (The *AIP Style Manual* suggests the Abstract should be about 5% of length of the article.)

## Paper Shibboleths:

Gilead then cut Ephraim off from the fords of the Jordan, and whenever Ephraimite fugitives said, ‘Let me cross,’ the men of Gilead would ask, ‘Are you an Ephraimite?’ If he said, ‘No,’ they then said, ‘Very well, say “Shibboleth” (שִׁבּוֹלֶת).’ If anyone said, “Sibboleth” (סִבּוֹלֶת), because he could not pronounce it, then they would seize him and kill him by the fords of the Jordan. Forty-two thousand Ephraimites fell on this occasion.

—Judges 12:5–6, NJB

My dictionary defines “shibboleth” as a peculiarity of speech that distinguishes a class of persons. I enlarge that definition here to mean a seemingly trivial peculiarity of usage that results in hugely disproportional results (death in the case of the Ephraimites). Scientific writing has many constraints/details/shibboleths which must be followed in order to be published. (Hence a 65 page *AIP Style Manual*.)

In the opening quotes to this chapter, Maestro Stravinsky opines that constraints encourage creativity and result in “precision of execution”; Anonymous suggests satanic torture in meeting meaningless details. I believe at the end of this process you’ll most likely side with Anonymous. Oddly enough many of these writing details are designed to *reduce* your audience: consistent information placement (for example in Abstract or Conclusions) allows the reader to read only what is immediately of interest (and perhaps skip your paper entirely after perusing your Abstract and Figures). Selective use of italics makes the mathematics (high information content) immediately obvious. True Maestros of scientific writing create wonderful scientific papers even with the constraints. I hope that your liberal arts education has helped you develop an effective, interesting writing style. **However** in this writing exercise, I’m going to be evaluating your attention to the stupid details required by (for example) the *AIP Style Manual*. Frankly it would be asking too much to require you to get all these details right on this first try, so I outline below a small subset of critical formatting details that will affect your grade.

1. **Proper formatting of mathematics:** Letters standing for quantities (variables) are set in italics and are identified/defined in the text. (The names of compound quantities, like vectors or matrices, may be set in a font distinct from that for simple quantities. For example, vectors are often set in bold.) Of course, non-letter math glyphs: 1,2,+,=, ... are set upright. Letters that are not variables (like “sin” in  $\sin \theta$  or “max” in  $\theta_{\max}$ ) are also set upright. Many word processors have an “equation editor” to make these font changes almost automatically. Equations that include more than a few simple terms are “displayed”: isolated from the words on a new line. Displayed equations are numbered consecutively from the start of the document (or chapter in a book).
2. **Proper formatting of figures:** With the exception of actual photographs, figures should be “vector graphics”, like PostScript or SVG, not as pixel-based “raster graphics”, like jpeg or gif. Every figure includes a caption and is numbered consecutively

from the start of the document (or chapter in a book). Text in figures (for example axis labels) must be legible even when the figure has been reduce to a few inches in size. The background of plots is blank (lacks the horizontal lines favored by spreadsheets). Generally figures “float” to the top or bottom of a page; they are not embedded within the body of the text. Figures you did not create yourself (e.g., copied from the web) include a credit to the actual creator.

3. **Proper referencing:** This is an example of “Do what I say, not what I did”. The “References” in this document are not in the proper form for a paper. (They are intended as a bibliography: sources that could be consulted for clarification or expansion.) Every item in your References must be cited somewhere in the text. The exact format of references/citations differs a between journals. There are two major systems: numbers in the text linked to numbered sources in References and (author, year) in the text with an alphabetical listing of sources in References. Professionally a program like `BIBTEX` is usually used to manage both the basic reference database and the formatting of it in the style required by a specific journal. For this paper simply consistently use a reference format that will allow me to look up your references. **Rule:** You must cite at least two sources from peer reviewed journals/books. (You will probably additionally cite this lab manual, but it is not a peer reviewed journal/book.) As I intend to actually look up your references, if a reference is not immediately available to me (e.g., you received it via ILL or currently have the book checked out), include a copy of the reference with your paper.
4. **Plagiarism:** Detection of plagiarism is now trivial and an army of people enjoy outing famous authors for sins that would have gone undetected two decades ago. You must learn to avoid plagiarism, which I here define<sup>1</sup> as 20 consecutive words 90% in common with published work. If you’re going to plagiarize, at least make detecting it an interesting challenge for me. For example, do not plagiarize this manual: I wrote it and I remember what I wrote. It’s an interesting sporting question whether to plagiarize from cited or non-cited works. Clearly its easier for me to check cited works, but you then have the excuse that you weren’t seeking the original scientific credit: a thief of words not discovery credit (misdemeanor not felony). If you are caught plagiarizing from uncited works no excuse will save you. If you must exactly reproduce the words of a published source, you must put those words in quotes, not just cite the source. Finally, note that trivial word substitutions do not solve plagiarism: you really must re-express the ideas in the source in your own words.
5. **Units, sigfigs, errors:** The usual rules apply (see *Lab Lint* from 191). Essentially every quantity in your paper will have units and an uncertainty. The uncertainty will have no more than 2 significant digits. The place-value of the rightmost digit in quantity and error will match.
6. **Draft Required!** The course requires both a draft and a final-version of the paper. 40% of the grade will be determined by your draft. Let me be clear about this: a draft is not an outline. It should be much the same length as the final paper; it should be composed of English sentences. The figures and displayed equations in the draft may be hand-drawn. The text of the draft should be complete (including, for example, figure captions). A draft is not a final version submitted twice. (The final version must respond to the comments I make in the draft.) If you do not submit a draft (e.g.,

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<sup>1</sup>FYI: online checkers like `turnitin.com` flag as potential plagiarism matches of 6 words.

if you submit an outline or you submit nearly identical “drafts” and “final” papers) your maximum grade for the project will be 60%.

Important rules which you should follow (but which will not result in deductions).

1. **Equations are part of sentences:** Punctuation (comma, period) may be required by English usage at the end of displayed equations. Before the start of a new sentence, there should be a period from the previous sentence. (If you look carefully at this manual, you’ll find I violate this rule when I think dots at the end of an equation might cause confusion. Journals would not allow any exceptions.)
2. **Proper formatting of tables:** The *AIP Style Manual* has a full page of instructions and many pages of examples on formatting tables. Frankly, following these rules is difficult without a typesetting program like L<sup>A</sup>T<sub>E</sub>X (which is briefly described below). I will mention one detail which surprised me when I was first informed of it: no vertical lines in tables.
3. **Special words:** The *AIP Style Manual* has more than ten pages of preferred spellings and abbreviations

## T<sub>E</sub>X and L<sup>A</sup>T<sub>E</sub>X

Because of the special formatting of scientific papers, most papers in math and physics are today typeset using the program L<sup>A</sup>T<sub>E</sub>X. Most of the physics lab manuals and exams you’ve seen have been written in L<sup>A</sup>T<sub>E</sub>X. I love L<sup>A</sup>T<sub>E</sub>X: I’ve been thinking of getting a “I♥T<sub>E</sub>X” bumper sticker or a photo of Don Knuth to put up in my office. But T<sub>E</sub>X really is both difficult to learn (it’s more like programming than writing) and stubborn and unyielding in action. Only if you are thinking of going on to grad school in math or physics is it worth your time to start to learn this beast. If you decide to give it a try, I promise to work with you until you achieve the results desired.

In the on-line folder **Examples+tex** I’ve pulled a variety of papers from the web. The **.pdfs** in that folder show you the results; the subfolders show the “source” that produced that output. If you’re not interested in T<sub>E</sub>X, view the **.pdfs** just to see what a scientific paper looks like. As noted in **files.txt** John Dumm, Eric Garlid (Patton), and Ari Palczewski were 2005 SJU physics grads. Each is now closing in on a PhD (which typically requires publishing some scientific papers) and I’ve pulled an example for each. Ross Terhaar supplied me with the paper he wrote (in Word, I believe) for this course in 2010 (**RossT2010.pdf**). I converted his words into T<sub>E</sub>X to make the paper **RossT2010rev.pdf**. If you look at the details of these papers you’ll see minor differences in style, that reflect the required style of the journal. (Examples: Figure 1 vs. FIG. 1; Table 2 vs. Table II; 6 Conclusions vs. VI CONCLUSION; [Leybold Scientific, 2006a] vs. [2]) One of the nice things about T<sub>E</sub>X is that minor changes to the **documentclass** can automatically change these formatting details if you decide to switch from, say, Phys.Rev. D to Ap.J.. Essentially all journals distinguish between **preprint** style (typically one column, double spaced: good for corrections) and **reprint** style (as it would appear in the journal, often two columns with smaller fonts).

## References

1. Birgitta Malmfors, Phil Garnsworthy, and Michael Grossman *Writing and Presenting Scientific Papers* (Nottingham Univ. Press, 2nd ed., 2003) T11.M34 2004 Alcuin Reference
2. Robert A. Day *How To Write & Publish a Scientific Paper* (Oryx Press, 5th ed., 1998) T11 .D33 1998 Alcuin
3. Briscoe, Mary Helen *Preparing Scientific Illustrations* (Springer-Verlag, 1996) Q222.B75 1996 Alcuin
4. Jane Miller *The Chicago Guide To Writing About Numbers* (Univ. of Chicago Press, 2004) T11.M485 2004 Alcuin Reference
5. Ivan Valiela, *Doing Science: Design, Analysis, and Communication of Scientific Research* (Oxford, 2nd ed., 2009) Q180.A1 V35 2001 Alcuin
6. <http://www.physics.csbsju.edu/370/papers/links.html>
7. Karin Knisely *A Student Handbook for Writing in Biology* (W.H. Freeman, 3rd ed., 2009) — more than a hundred pages on using Word/Excel for scientific writing; ILL only