Writing a scientific paper

John Martinis, Oct. 2012

0) General Comments

a) Break up paper into 7 sections, as detailed below. For this class, use section headers. Short scientific papers may not have actual headers, but the reader will recognize the separate sections.
b) Title and abstract is short advertisement of paper, to encourage others to read your paper.
c) Reader should get basic idea of paper by reading title, abstract, introduction, figures + captions, and conclusions.
d) Figures + captions is pictorial summary– should explain your work by itself. This is useful to catch the attention of busy people.
e) Figure captions should be concise, but define data and summarize graph.
f) Try to introduce no more than one concept per sentence. If break this rule, make sure the concepts are simple.
g) Think carefully about how to sequence figures, results and explanations for clarity.
g) Add references when needed. They are useful as you can quote a result without having to derive or discuss it in detail.

1) Title & Abstract – A short summary of your experiment.
a) Rewrite this last, once you fully understand your experiment and paper.
b) Length is one paragraph, 5 to 10 lines. Use approximately one sentence per section.
c) Pick a good descriptive title.

2) Introduction – Why should readers be interested in your paper?
a) Start with general principle that is being tested, and why it is interesting to physics.
b) Include history – what was done before, what are you testing new here.
c) Include why this may be important for applications in science and technology.
d) Start discussing background physics to explain the basic physics of your system.
e) This section is usually the hardest to write, but most important for journal acceptance.

3) Theory – Background information to understand experiment.
a) State or review basic theory needed to understand your experiments.
b) Its fine to state basic assumptions, and then state formulas without derivation. If complex, include intermediate steps. Assume your audience is expert, so they can figure out intermediate steps. Remember this is an experiment, not a theory paper, so keep the discussion concise.
c) Figure of experiment usually is placed here.
d) Make sure you define terminology and variables properly and logically (order is important).
e) Keep the physics here basic and simple as possible so as not to lose the reader. Subtle details and new physics, such as theory for check experiments, is better introduced later in the analysis section.

4) Experimental Methods – Document what you did so the experiment can be repeated.
a) Give enough detail so experiment can be repeated, but not too much about trivial issues. It's an art to know how much to talk about, but now more is better - your advisor will cut out the stuff that just can be assumed.
b) Be concise here. For most items you want to just state, not explain.

c) Write fully about any tricky, unusual, surprising methods you needed to do to successfully execute the experiment.
d) Be logical in order you present methods. Build on ideas you have already discussed.
e) Refer to sketch often, or add figures or pictures if needed.
f) Double check that all variables or parameters are defined.

5) Results – Use sequence of graphs to tell a story.
a) Plot all figures before writing paper, since this is backbone of paper.
b) Use a series of figures to tell a story, from simple data taking and its results, to more complex analysis of your data. Be logical in the order of the story, building upon concepts you have already explained.
c) You do not have to show all raw data in the more complex figures.
d) Discuss check experiments. Add figures if important and/or appropriate. This could go into an appendix, if such experiments chop up the flow of your writing. When lacking space in a short scientific paper (Nature, Science, Physical Review Letters), write a supplementary paper with additional figures and text.
e) In text, walk person through the data in the graph. Explain x and then y axis, discuss how data changes with x variable. The data is obvious to you, but not your reader.
f) After discussing the trends of the data, explain where errors come from, and error bars.
g) Remember, your data describes an investigation of nature, and is "correct" all by itself. If you believe your data and it does not correspond to theory, its fine, but the radical nature of the results will make it harder for others to believe and get the paper accepted.

6) Analysis – Explain how your data makes theoretical sense.
a) The analysis section is often intertwined with results, so you can combine into one section. This is especially useful if using a sequence of increasingly complex graphs to explain results.
b) It is convention to plot data as points, theory as lines. Plot them together so the reader can immediately see if your experiment makes sense.
c) Best to plot data such that theory is on a line (all lines are straight) – anyone can then check for agreement.
d) Sometimes easiest to explain if theory is curved, but think carefully why doing this.
e) Does the theory go through experimental points with error bars? Small deviations within error bars are fine, as well as a few slightly outside the bars, but large ones need to be discussed as possible systematic errors. Also, error bars being much bigger than deviations also need to be discussed, since it implies you underestimated errors.
f) Introduce here more complex theory, or check theory, if needed. These are important details of understanding the experiment that best goes in the main body of the text.

7) Conclusions – What was learned or discovered in the work?
a) Short paragraph summarizing the results.
b) Also can discuss in another paragraph any further applications, directions of research, or implications of your results.
c) If you had significant discussions or help in the experiment, please acknowledge in one or two sentences in a separate paragraph at the end of the paper. You also acknowledge your funding sources here – this is very important.