How to Write a Scientific Paper

What is the point of writing a scientific paper?

The purpose of a scientific paper is to show the rest of the world what wonderful things you have done in science. (Well, in professional science it's a little more boring than that: it's to communicate the results of your latest experiment so that rest of the scientific world can benefit from what you have done.) Professional scientists make their reputations by publishing papers at a rate of several papers per year.

A "paper" is a kind of scientific essay - a combination of essay and lab report - in which you describe accurately (and without sensationalism) what you did and what you learned from it -- what you would call your "findings".

Every paper requires some form of novelty -- something new that the paper brings to the science world. Papers which merely rehash material which already exists in the literature do not get published. The novelty may be a new phenomenon which has been discovered, or a new technique applied to an existing phenomenon, or an existing technique applied to a new type of problem, etc.

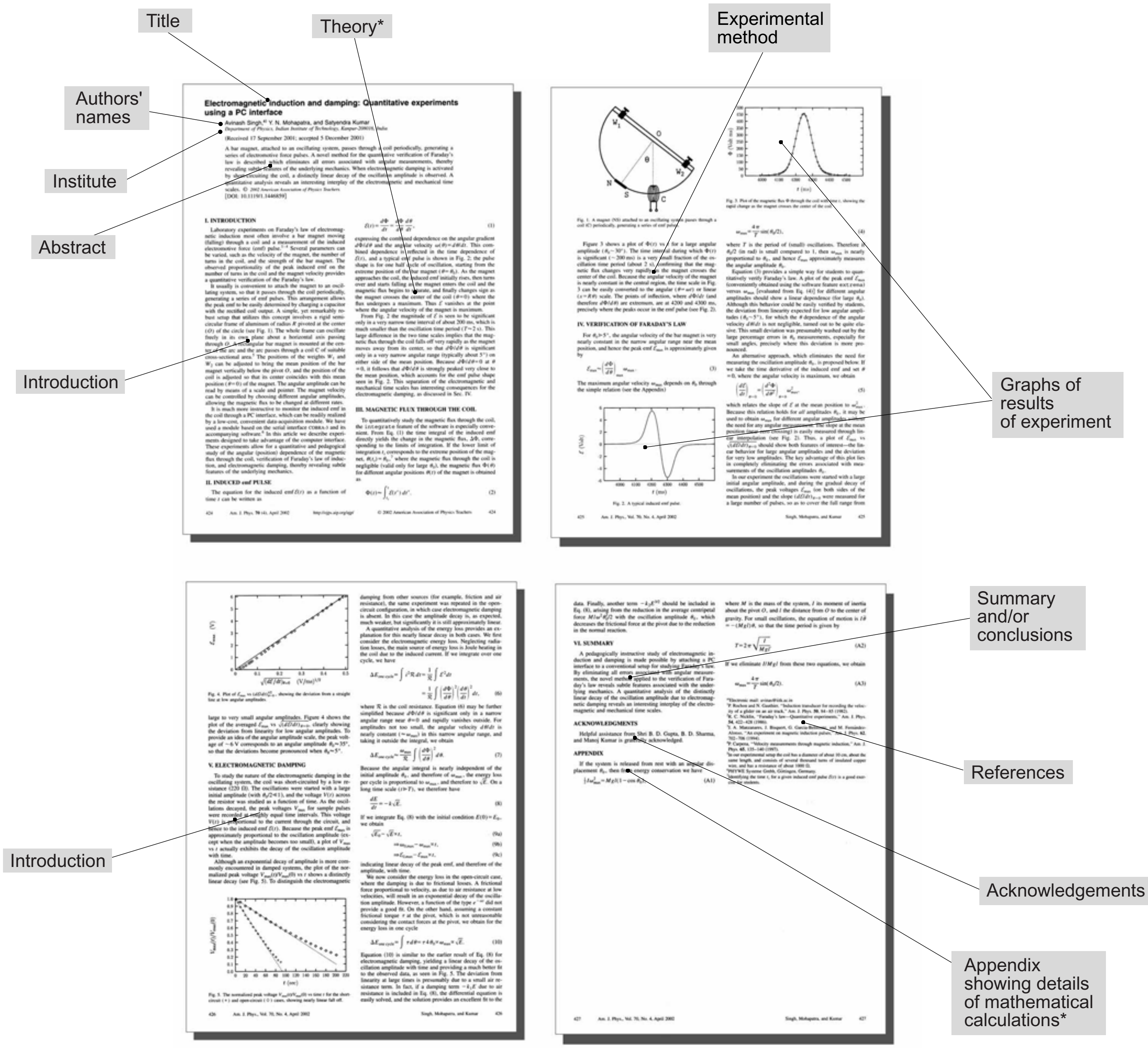
Where do you you get a scientific paper published?

In the world of professional science there are thousands of scientific journals which publish thousands of scientific papers. Most are published monthly, some are published quarterly and some only yearly. Some journals become so popular (in the sense that everyone wants to publish in them) that they "split" and form two journals. A good example is the Journal of Physics, which now has become the Journal of Physics A, Journal of Physics B all the way through to Journal of Physics E. Readers (individuals and libraries) pay to subscribe to each journal so that they can keep up with what is happening in their field. University libraries subscribe to hundreds of journals, typically paying a subscription price of several hundred dollars per journal. Scientists who publish in journals typically have to pay a "page fee", for instance $250 per page, in order to get their paper published in a particular journal. The more prestigious the journal, the higher the page fee.

The Canadian Journal of High School Physics is a scientific journal in which high school science students pulish. No page fee is charged but CJHSS follows the same publishing guidelines as other professional journals.

What does a Scientific Paper Look Like?

The scientific paper shown below illustrates the various compoents of a paper. The sections marked with an asterisk do not appear in all scientific papers. (Which sections appear depends on the content of the paper.)



Some papers are only one page long while other papers are 10 or more pages in length. Flowery prose is discouraged in scientific writing. Scientists usually want to "get to the facts" as quickly as possible. It helps to have enough diagrams and graphs that the reader is not presented with "wall-to-wall" text.

GOOD ADVICE: Don't make your paper "wordy". Make it visually appealing by using diagrams and graphs.

The Components of a Scientific Paper

Title

Good Title:
Evidence of bacteria in meteorites of Martian origin

Bad Title:
Evidence of life in outer space

Terrible Title:
Your uncle came from Mars!

In this section you will learn how to write each one of the individual parts of a paper. To learn more, search the internet for copies of scientific papers and study them.

The TITLE of your research paper titles should describe accurately what your paper contains. Don't make a title which make grand, sweeping claims. (Many professional papers suffer from claiming too much in a title. This wastes the time of researchers when they search for information on a topic.)

Grammatically, a title is usually what an English teacher would call a "noun phrase". Titles may also be phrased as questions but this is less common and should be avoided.

Avoid vague, inaccurate or amusing titles and at all costs, avoid being "cute". This tends to cheapen the quality of the article. Remember: it is a scientific paper, not an article for a tabloid newspaper. You are not trying to attract readers with "lurid headlines". In no case use an explanation mark in a title.

Abstract

GOOD ADVICE: Write the abstract after you have written the paper. Try to keep it less than 150 words.

The ABSTRACT is a short paragraph at the top of the paper which explains what the paper is all about. It states the objective very briefly (but accurately), gives a quick overview of the contents of the paper and summarizes the results. The purppose of an abstract is to allow a person who reads only the abstract to tell whether it is worthwhile to read the entire paper. (Some publications only publish abstracts; most journals provide abstracts on the internet.)

Introduction

GOOD ADVICE: Make it clear in the Introduction what the problem is that you are investigating. It doesn't have to be stated in the form of a hypothesis.

The purpose of the INTRODUCTION is to give the paper a context and a purpose. It may ask a thesis question or state a hypothesis. (Note: You are not required to teach the reader everything there is to know about the topic. Just include enough background so that a student with a modest amount of knowledge on the topic will be able to follow your paper.)

Inform the reader about the significance of the problem you are investigating. This will help establish in the mind of the reader that your findings are also important. In general, keep the introduction to about 1/4 page or less.

Theory

In some papers you will need to include a section called **THEORY** which tells the reader what he or she needs to know in order to understand the results of your experiment. This is especially true if you are comparing experimental and theoretical results.

Don't provide too much theory. You are not trying to write a textbook so make lots of references to other books or papers which explain the theory in more detail. If mathematics are used, make sure that all mathematical symbols are defined. Try to keep the theory section to a few paragraphs. There is a general tendency for theory sections to be too long.

> ***GOOD ADVICE: Put any detailed theory in an Appendix. Note, however, the reader should not actually have to read the Appendix to understand the paper.***

Experimental Method

The **EXPERIMENTAL METHOD** (or sometimes just **EXPERIMENT** or **METHOD**) describes what you actually did to get your data. It does not describe what you intended to do, nor it does not contain vague statements such as

"We set up the apparatus and took some measurements."

Show one or more diagrams of your apparatus and describe what is in the diagram. Make sure that you describe important construction or alignment details. A commmon mistake which beginners make is to try to write a series of steps for the reader to follow. Keep in mind that the reader doesn't want to actually repeat your experiment; he or she simply wants to understand it.

The order in which you describe your experimental method may not be exactly the order in which you did things. Do not describe any blind alleys you went up (unless there is good reason to do so) and don't load up the method with personal anecdotes or other trivia. Readers bore easily.

The best way to learn how to write an Experimental Method is to read some. Search the Internet for "scientific papers"; you will find thousands of them.

> ***GOOD ADVICE: Do not write the method as a set of steps. You are not writing a recipe for someone selse to follow.***

> ***GOOD ADVICE: Find some papers and read them. Better yet, consult some papers from the journal you are publishing in.***

Results and Discussion

The **RESULTS AND DICUSSION** section is very important. (**RESULTS** and **DISCUSSION** may be two separate sections or a single section.) Beginning writers often get the idea that the **EXPERIMENTAL METHOD** section is the most important so they spend most of the words describing what they did. Then they plunk in a bunch of tables showing all the numbers they measured.

> ***GOOD ADVICE: Don't put in any data tables at all. No one wants to read them.***

> ***GOOD ADVICE: Think graphically.***

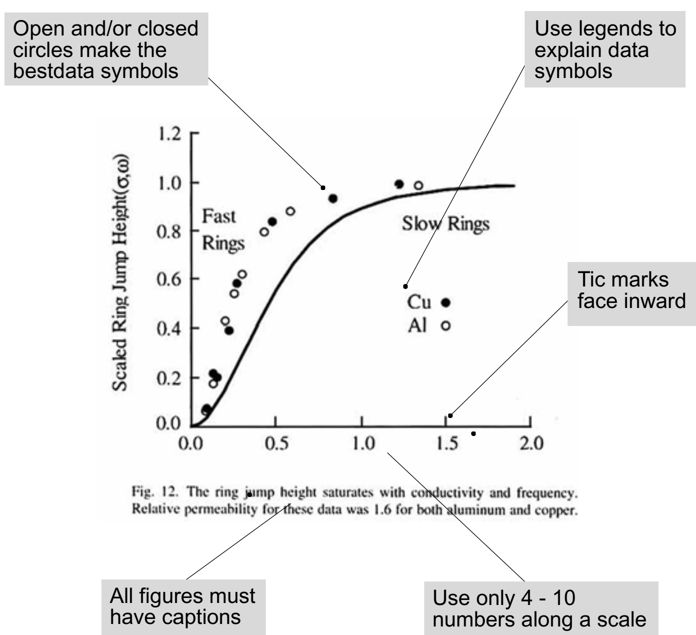


Fig. 12. The ring jump height saturates with conductivity and frequency. Relative permeability for these data was 1.6 for both aluminum and copper.

Present your results in some easy-to-understand graphical form (such as a line graph or a bar gaph). Remember, it is your job as the author to analyze the data and it is your job to present it to the reader in a form which can be readily understood.

Use line graphs wherever possible and follow the style used in the example shown here. Make sure that the detail of the graphic is large enough to be readable at the scale at which it will be printed. Design the graphic so that it can be scanned at 300 dpi and supplied to the journal as a JPG file. *(Note: Most graph-drawing programs do a very poor job of making publishable-quality graphs. Use a drawing program such as* CorelDraw *or* Illustrator *to do proper linework and lettering. Excel graphs are acceptable. In any event, provide the graph as actual source and not just as a 300 dpi JPG file.)*

Use diagrams effectively but don't put in so many that the reader can't find the text for the diagrams. ***Do not, under any circumstances, put in photographs, diagrams or graphs just for decoration.***

You must present your results in an impartial manner. If you compare your results to other results which have been published ("results in the literature", as they say), do not praise your results to the skies while trashing the results of others. As a scientist you want to be impartial. Your method undoubtedly has weaknesses too and you should be prepared to point them out to the reader. You are trying to be objective, not smug.

Why can't you just let the reader figure out what it all means for himself or herself? The answer is simple: it's your job to discuss what your data mean; it's not the reader's to try figure it out. Your readers are not going to take the time to do all that. If you have achieved important results, then you must say so.

You are entitled to speculate on what your results mean. You also are required to relate your findings to what other researchers have found. If your results contradict findings elsewhere in the literature, then it is you have to discuss what this means.

Conclusions

GOOD ADVICE: Try to make a strong conclusion. Good papers do not have wishy-washy conclusions.

Draw fair conclusions, but do not make conclusions which are not supported by your data.

THE CONCLUSIONS YOU DRAW MUST BE SUPPORTED BY YOUR RESEARCH. DO NOT DRAW CONCLUSIONS WHICH ARE CONTRADICTED BY YOUR OWN RESEARCH!

Your conclusions must be drawn from your own findings, not those of other authors. You may certainly agree with the findings of others, or you may disagree. You may even make strong claims on the basis of your experimental results. However, remember that

EXTRAORDINARY CLAIMS REQUIRE EXTRAORDINARY EVIDENCE!

In your conclusions, which can be broader than what you conclude under **RESULTS AND DISCUSSION**, refer back to your objective (which will be found in the **TITLE** and in the **INTRODUCTION**. This you must do. You must relate "what you got" to "what you set out to do". If you haven't done this, your paper is not finished.

In your conclusion you should make a general statement concerning the summary of the results you found in your **DISCUSSION**. You may also make recommendations as to how the experiment could be improved, or suggest other ways in which the experiment could be repeated ("replicated"). Or, you might make suggestions for other experiments that could be done to further the research in this area. (Be careful with this one: *if this is your only conclusion then you don't have much of a paper!*)

Acknowledgements

In the **ACKNOWLEDGMENTS** section can thank anyone who helped you significantly, either in suggesting the experiment, doing the experiment, providing materials or facilities, or in writing the paper. In particular you should acknowledge the support of your teacher sponsor.

GOOD ADVICE: This isn't the Academy Awards, so don't thank everyone you ever met.

Appendix

Some papers require detailed background or theory in order to be understood. If you feel that you have material which *must* be presented, put it in an **APPENDIX** which goes at the end of the paper. The **APPENDIX** is understood to be optional as far as the reader is concerned. The reader should be able to comprehend the paper without reading the appendix. (You should understand also that just about no one will ever read an appendix so think carefully about whether or not you really need one.)

GOOD ADVICE: Leave it out.

References

A paper does not have a bibliography. Instead, it has a section called **REFERENCES** in which you place all references to papers and books that you have read. The exact format for the **REFERENCES** depends on the journal you are publishing in. A reference to a paper typically will appear something like

> [3]Y.Brainan and I. Goldhirsch, "Taming chaoitic dynamics with weak periodic perturbations," Phys. Rev. Lett. **66**, 2545-2548 (1991).

The journal being cited in the above reference is called "Phys. Rev. Lett." which stands for *Physical Review Letters*. (In references, the journal name is usually abbreviated. Find out by looking at other papers the what the correct abbreviation is for a particular journal.) The bolded number 66 is the "volume number". The page numbers, 2545-2548, usually start at 1 at the beginning of the year for most journals and increase until the last issue for that year.

As shown above, the reference in the Canadian Journal of High School Science is given a superscript number. This same number is called out in the text in a manner similar to the following:

> **We show that the particle density is in fact a decreasing function of height except when only one particle is present.[3]**

A typical paper will have at least a half-dozen or so references. It is very unlikely in this day and age that any paper would be published without making reference to work that someone has done somewhere. (Remember, it is the experimenter's job to seek out other similar work that has been done, not the reader's.)

GOOD ADVICE: Make complete records of your references as you go along. They can be very difficult to find later.

What Kind of Writing to Use

Scientific writing is considered "heavy reading" by a lot of people. Some might also consider it "boring". However, what is boring to one person can interesting to another. If you come across another paper on the same topic as yours you become interested in it immediately no matter how badly it is written because you want to:

- find out if that person has already done your experiment (i.e., "scooped" you)
- learn more about the topic itself
- get more ideas for your experiment
- find out the name of another person who thinks like you do

Even if the writing is "heavy", you know something about the field so you don't mind the heavy reading. Having said all that, don't go out of your way to make your writing as boring as possible.

Writing Style

GOOD ADVICE: Use the "we form" for multiple authors and the passive voice for single authors.

There are three generally accepted styles for writing scientific papers:

1. The passive voice. The writer states what is done but does not state who did it:

> *A slightly used 57-g tennis ball was dropped vertically though a measured height of either 30 cm or 60 cm onto a solid wooden table top.*

2. The "we" form. The writer (or writers) use the "corporate we" or "royal we"when describing an actions which take place:

> *We dropped a slightly used 57-g tennis ball vertically though a measured height of either 30 cm or 60 cm onto a solid wooden table top.*

3. The "I" form. If the writer is a single person the "I" may be used:

> *We dropped a slightly used 57-g tennis ball vertically though a measured height of either 30 cm or 60 cm onto a solid wooden table top.*

Of the above styles, the "we form" is most common if the paper has multiple authors. Because science is supposed to be "objective", papers written using the "I form" can sound a bit too ego-centric. A paper which reads as "I did this" and then "I did that" followed by "I did the other thing" would probably read better if the passive voice were used.

At all costs stay away from naming actual experimenters: "Jerry held the stop-watch while I dropped a 57-g tennis ball...".

General Writing Hints

The reader has a right to expect that a paper at least be written with good grammar. There is perhaps nothing which puts a reader off more than having to wade through page after page of poorly crafted or ungrammatical sentences. Have someone proof-read your text. Have someone proof-read your text; it is sometimes difficult for an author to see his or her own grammatical short-comings.

GOOD ADVICE: Get someone to proof-read your text who is capable and willing to provide you good advice on writing. Then follow it.

Robert Day, in his well-known book called "How to Write and Publish a Scientific Paper" provides some facetious tips on good writing:

The Ten Commandments of Good Writing.

- Each pronoun should agree with their antecedent.
- Just between you and I, case is important.
- A preposition is a poor word to end a sentence with.
- Verbs has to agree with their subjects.
- Don't use no double negatives.
- A writer musn't shift your point of view.
- When dangling, don't use particles.
- Join clauses good, like a conjunction should.
- Don't write a run-on sentence because it is difficult when you got to punctuate it so it makes sense when the reader reads what you wrote.
- About sentence fragments.

How to Write and Publish a Scientific Paper, 5th edition by Robert A. Day. Phoenix, AZ, Oryx Press, 1998. 275p., ISBN 1-57356-164-9

It takes a while to learn how to write scientific English. Don't feel discouraged if this is your first attempt. Get help from your English teacher on the basics of grammar (see the Ten Commandments above). Have a few science teachers read it (especially your teacher sponsor). When it is submitted to CJHSS more comments will be given. If you follow the advice given in this document you will at least avoid a great deal of red ink on the manuscript.