

The Scientific Paper: A Template (with Tips for Managing MS Word)

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This document is intended as an outline for writing scientific papers. It contains all of the important sections that should be included in a scientific paper, as well as descriptions of what should be included in each of these sections. It also contains some useful tips on how to use Microsoft Word to write scientific papers. The easiest way to use this document is as a template, inserting your text and figures as described below. This section is the abstract. It contains a brief description of the project including a relevant description of the problem, data collection procedures and a summary of results, as well as a few pointers on how this information fits into the overall field. The abstract may contain equations such as $\vec{E} = \vec{E}_0 \cos(\vec{k} \cdot \vec{r} - \omega t + \phi)$, but inline equations in Microsoft Word don't look very good. An abstract is usually quite short. Often, the length is limited to between 200 and 400 words.

I. INTRODUCTION

This paper contains a general outline of the information that should be included in a scientific paper. It provides a good template from which you can easily structure a paper. When you start out writing papers, you will likely include most of these sections and utilize this fairly standard format. As you gain experience, you may choose a different ordering or different section titles as you find appropriate. Remember this is just a template to help you get started. You will develop your own style of writing.

Both an awareness of your target audience, as well as the actual content of your paper, determines how you will write your paper. Thus, the writing process will go much more smoothly if you take some time to answer a few questions before you begin writing. For example, ask yourself, "Who is my audience?," "What do I want them to get out of this paper?," "What are the most important ideas to convey in this paper?" There are lots of other questions you could ask, but these three will help you generate a document, which is pitched at the right level and contains information that is useful to your audience.

However, you should keep in mind that a good scientific paper *always* introduces the reader to the subject material and provides the appropriate background information that the reader will need. A good scientific paper will always make the experimental, computational, or theoretical methods clear enough so that a competent reader could in principle reproduce the work. A clear description of how any data was collected should be included, as well as some presentation of the raw data, generally in graphical format. Any analysis performed on the data should be outlined clearly. Analysis and conclusions drawn from the analysis should generally be described separately from the raw data. A paper should end with a set of conclusions based on the analysis. It is the responsibility of the author to carefully lead the reader from the experimental design through the analysis to the conclusions, tying each piece together. In other words, it should be clear to the reader explicitly how your analysis leads from your raw data to your conclusions. If you do not make this clear, no matter whether or not you are right, you have not done your job as an author and will find it difficult to convince anyone of the validity of your conclusions.

Finally, every paper should end with a references section. A scientific paper without any references indicates that the author believes that every thought conveyed in the paper is

original. Any information that you obtain from another source should be cited. The only exception is for facts, relationships or concepts that are considered *common knowledge*. As a student, your common knowledge will often be somewhat more limited than that of the average author in a scientific journal. As such, you will often reference information from class notes or textbooks that other authors may not. When in doubt, make a reference. This eliminates any possibility that you will be accused of plagiarism - a very serious transgression.

The introduction generally contains a brief overview to the material that will be presented. Relevant information includes a clear enunciation of the questions that will be addressed in the paper, background information necessary for understanding the paper, and potentially the basic theory needed to understand the contents of the paper (but do not duplicate all the material from Section II).

It is important to consider your audience when writing the introduction. The primary purpose of an introduction is to give your readers enough information so that they will be able to understand the rest of your paper and put it into a larger context. Depending on your audience, this context may vary. For example, if you are preparing a paper with other physics students in mind as the audience, you will write the introduction so that they see how their previous physics knowledge will be useful in understanding this paper. If, on the other hand, you are writing this paper for a narrow selection of researchers, you will not need to include as much information. Rather, you will present them with enough information so that they can see how this paper fits in with previous relevant research. In all cases, do not include information that does not tie in with the topic of the paper. Remember, the introduction must be an integral part of the entire paper, and cannot read as if it were designed as a stand-alone document. Correspondingly, its size must be commensurate with the rest of the paper; in other words, don't allow the introduction to dominate the paper.

This document will also serve as a template for producing professional looking papers in MS Word. Before you begin to modify this document, make sure you have a copy of it saved somewhere so that you can look back at it if you delete or otherwise lose something important in this document.

If you have any questions about the appropriate style for a scientific paper, you should refer the AIP Style Manual at <http://www.aip.org/pubservs/style/4thed/toc.html>.

II. THEORY

Often, if the theory needed to understand a paper is somewhat extensive, a separate section containing a development of the theory will be presented. This section should contain enough theoretical detail to make it possible for a member of your target audience to be able to reproduce any results you rely on later in the paper. Obviously, the amount of detail that you include will depend on space constraints and the expected level of expertise of your audience.

In the context of a paper written by an undergraduate for a class, you should include all non-obvious steps in derivation and be sure to reference material that is not “common knowledge.” If you just learned the material in a class, you might want to include references to the source of the basic derivation. If you start with a non-trivial expression that you had to look up somewhere, either in a book, a paper, or your notes, you should include a citation and reference.

All equations should be incorporated into the text using a program designed to properly format equations. *LaTeX*, *MathType*, and *MS Equation Editor* are common programs. You can insert equations easily into a document using *MS Equation Editor*. It is not the best, or the prettiest, but it works. Putting in equation numbers is not natural for Word, so this template contains a simple macro to do this. If you have *MathType*, it works better, so use it. Below is an example of how equations and their numbers should appear.

$$\vec{E} = \vec{E}_0 \cos(\vec{k} \cdot \vec{r} - \omega t + \phi) \quad (1)$$

$$\vec{B} = \vec{B}_0 \cos(\vec{k} \cdot \vec{r} - \omega t + \phi) \quad (2)$$

Never use ordinary script for any equation, whether inline or numbered.

III. EXPERIMENTAL METHODS

This section is often called experimental design or methods. It contains information about the experimental setup, design, instrumentation and procedure. The main purpose of this section is to convince your reader that your experimental methods were sound and thorough. If you do not clearly report your experimental methods, you run the risk of having someone else repeat your experiment and get different results. (This then brings into question the validity of your conclusions and your reputation as a scientist.)

Often you will include a diagram of the experimental setup. An example is shown below. Diagrams can be drawn using any software you are familiar with and imported into Word. If the diagram is particularly simple, you can even use Word itself to draw it.

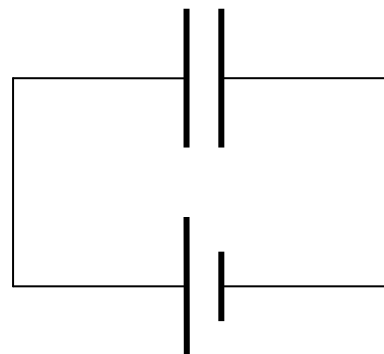


Figure 1 : A capacitor and battery circuit diagram. (Notice no title in the figure.)

Any diagram you include should contain a fairly detailed figure caption. A good rule of thumb is that if someone reads the abstract and looks at all the figures and captions, they should have a reasonable idea what your paper is about. While this isn't always possible, it is a good goal to have. (That said, this document does not even come close to meeting that requirement, but it also is not so much a scientific paper as a how-to manual on writing one.)

As mentioned before, you should include enough information in your experimental design to make it possible for someone else to reproduce your experiment. You should generally outline what you did with enough detail so that it is clear how you set up your experiment, what types of instrumentation were involved (detailed make and model numbers are not required), and how you collected your data.

IV. RESULTS

Your paper should contain a section describing/presenting your raw results. Often you will be able to do this by including graphs and/or tables of data. This data should generally not be heavily processed. Rather, one should include results in formats that are good representations of the data obtained by your experiment or computation. You will have a chance to show processed results in the analysis section, but in this section you need to present the reader with your raw data so he/she can clearly judge the quality of your analysis and conclusions. It is your responsibility to estimate experimental error/uncertainty.

Often you have far too much data to include it all. In this case, you will include a sample of your raw data with tables or graphs containing straightforward compilations of this data. It is very typical that only a small fraction of the data you have collected shows up explicitly in the paper.

Below is another figure. It is generally best to make all figures of single-column width (unless your paper is single-column). When they are inline, it is very easy to locate them with respect to text [3]. You may still have to do some fiddling at the end to get them exactly where you want them, but once you put them somewhere, they stay put with respect to the text.

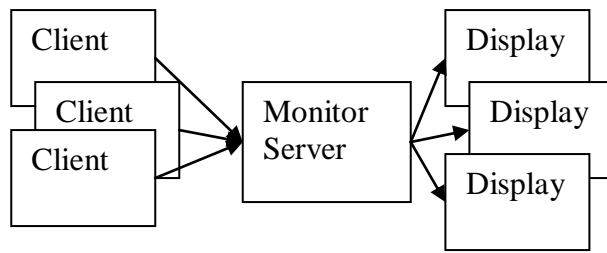


Figure 2 : A high level diagram of the monitor system. Monitor data flows from left to right, and requests for particular monitor data from right to left. The Monitor Server (MS) caches replies from the clients.[4]

You can also insert Tables very easily. Just make a table

Current	Voltage	Power
0.01	0.12	2
0.02	0.13	4
0.03	0.14	6

Table 1 : This is a simple Table to demonstrate how a table should be inserted

In general, you should never include a table in a paper when a figure/graph will do a better job. It is quite rare to see tables in scientific papers. You should never include a long list of data or an excerpt from a spreadsheet unless the particular values in the list are very important. Long lists are hard to read and generally confuse or bore your reader.

Most often tables are used to show a few numbers derived from a larger dataset. This is a good use of tables but should generally occur in the analysis sections because the numbers are derived from the data.

Here is another table. We can reference this table in the same way mentioned in Section II. Table 3 shows a more common type of info to be contained in a table. This table shows the different sources of uncertainty in a measurement and how much each source contributes to the total uncertainty.

Sources of Error	Size of Error
Statistical Uncertainty	$\pm 0.02 eV$
Systematic Uncertainty	$\pm 0.10 eV$

Table 2 : This table shows the different sources of uncertainty in a measurement.

V. ANALYSIS

After you have clearly presented your results, you now describe how you have analyzed these results, i.e., how you will process the data you collected to obtain information that will help you answer the questions raised in the introduction.

It is critically important that the analysis section of a paper is clear. Your job in the analysis section is to convince the reader that the methods you used to get from your results to your conclusions are sound. If your analysis section is

incomplete or unclear, your reader may not trust the conclusions you draw.

This is another section where you will often have equations, graphs and tables. Remember that whenever you use an equation, graph or table, it should be referred to in the text. Any equation, graph, figure, or table should fit into the general flow of your development. If you include a graph but do not mention it in the text, the graph either has no reason to be included, or you have omitted important information from the text.

One fairly common mistake is to make this section too brief relative to the other sections. It is important to outline in enough detail how the raw data was manipulated to extract useful answers. These manipulations often involve fairly intricate mathematical/numerical procedures, such as Fourier Transforms, curve fitting, linear regression, numerical integration, smoothing, normalizations, to name a few common examples. Such procedures have to be described in the text of this section.

VI. CONCLUSIONS

Your conclusions section should be brief, but long enough to refocus the reader. The conclusions section highlights the validity of your assertions/conclusions, making reference to your data/analysis. In essence, it summarizes the answers to the questions you asked in the introduction.

You should also make it a point to place your conclusions within a proper context. That is, you should discuss the possible implications of your conclusions, or how they might be relevant to other researchers. This is often hard to do as a student, but not impossible. Some questions you can keep in mind when writing this section are: "Why are these conclusions important?," "Whom might these results affect?," and "What could these results be useful for?"

It is important to keep in mind that you should not overstate your case. A common error authors make is to over-generalize. For example, if I find that a particular type of crystal behaves nonlinearly within certain parameters, it is an over-generalization to conclude that all crystals of that structure will behave the same way, or that the model continues to hold outside of the tested parameter range. If the author suspects this to be the case, he/she can state this hypothesis but should not assert it as a fact. This leads us to a final section which you may or may not want to include.

VII. SUGGESTIONS FOR FURTHER RESEARCH

This section contains a speculation on possible future directions that are likely open to exploration. For example, in what ways could this research be extended? It can be a list of possible future experiments or questions one might ask that are based on the results of the research presented. This section gives the author the opportunity to be somewhat more creative/speculative. That said, it should be clear in the paper that the statements made in this sections are suggestions, conjectures and/or best guesses. This section can sometimes be included with your Conclusions.

VIII. REFERENCES (THIS WILL TYPICALLY NOT BE A SEPARATE, NUMBERED SECTION IN YOUR PAPER.)

You must include a references section in any scientific paper. To omit the references section is to almost certainly commit plagiarism. As mentioned before, you should include references whenever you have used information from another source. This might be a professor's notes or a textbook. As you advance in your studies, your references will increasingly come from journal articles, since these articles generally present more recent results. Direct quotations are to be absolutely avoided; instead paraphrase your source.

The following few sections are generally not included in a paper, but are placed here to help you work with MS Word. If you read them carefully and use this document as a template, you will almost certainly save yourself a lot of pain and suffering associated with formatting documents. Better yet, learn to use *LaTeX*. It is installed on all the Macintosh machines and generates beautiful output with a minimum of fussing over formatting, although some new syntax must be learned in the process. (Still, it is highly recommended that you eventually learn to use *LaTeX*. That said, you can usually get by with MS Word unless you have a large number of mathematical formulas.) The following few tips will help make your life with MS Word more bearable.

IX. AVOIDING UNEXPECTED BEHAVIORS

Many of the problems people have working with MS Word stem from its broad functionality. When using MS Word, it is very easy to get confused because it is doing something automatically of which you are unaware.

Common problems include moving figures around when other text is moved. To avoid this, always put figures and captions inline, rather than as overlays. Never use wrapping with figures. It almost always causes problems [2].

Using 'styles' can be key to uniform document formatting. It allows you to think about your writing instead of the formatting. The style menu is straightforward to use: just select some text and choose the appropriate style from the style selection box.

It's generally a bad idea to force page breaks, but sometimes it is necessary. You will notice that there is a section break at the end of the references section. At section breaks, you can change the formatting/page layout. For example, this document is set up with two columns in the standard journal style, but you can change this style to single-column, double-spaced very easily. You can define different sections of your document to have different column properties, but you cannot mix column properties within a single section.

REFERENCES

- [1] I. Newton, "Apples Hurt when they Hit you in the Head," *Journal of Fruit Dynamics* (1521), **21**(3), 321.
- [2] W. Tell, I. Newton, "Arrows Hurt more than Apples," Private Communication.
- [3] R Feynman, M. Fandango, "Quantum Interactions between Apples and Arrows: A Diagrammatic Approach," <http://www.fruitdiagrams.org>.
- [4] C. Ape, "Learning to Climb like a Monkey," *Primate Dynamics* (2001), **4**(10), 57-69.
- [5] K. Kong, "Learning to Club like a Gorilla," *Journal of Newtonian Mechanics and Ape Behavior*, **12**(3), 125-130 (2003).