Fourteen Steps to a Clearly Written Technical Paper

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A technical paper will usually have four sections. The purpose of each of these sections is as follows:

Section I: Introduction
The introduction should do the following:
1. Open up the subject. (The subject will be electromagnetic fields in cylindrical dielectric geometries, adaptive arrays in packet radio, or whatever.)
2. Survey past work relevant to this paper.
3. Describe the problem addressed in this paper, and show how this work relates to, or augments, previous work.
4. Describe the assumptions made in general terms, and state what results have been obtained. (This gives the reader an initial overview of what problem is addressed in the paper and what has been achieved.)
5. Overview the contents of the paper. ("Section II contains our formulation of the problem. Section III contains the experimental data...")

Section II: Formulation of the Problem
This section should do three things:
1. Define the problem to be considered in detail. Typically this section might begin with something like: "Consider a packet radio system consisting of a single central repeater surrounded by user terminals. Each user transmits packets to the central repeater using a slotted ALOHA protocol [1]. The transmissions from all users are assumed to be on the same frequency..." The discussion should proceed in this way until the problem is completely defined.
2. Define all terminology and notation used. Usually the terminology and notation are defined along with the problem itself.
3. Develop the equations on which your results will be based and/or describe any experimental systems.

Section III: Results
This section presents the detailed results you have obtained. If the paper is theoretical, you will probably show curves obtained from your equations. If the paper is experimental, you will be presenting curves showing the measurement results. In order to choose the proper curves to present, *you must first be clear what point you are trying to convey to the reader*. The curves can then be chosen to illustrate this point. Whether your paper is theoretical or experimental, you must provide a careful interpretation of what your results mean and why they behave as they do.
Section IV: Conclusion
This section should summarize what has been accomplished in the paper. Many readers will read only the Introduction and Conclusion of your paper. The Conclusion should be written so they can be understood by someone who has not read the main work of the paper.

This is the common format for an engineering paper. Of course, the names of the sections may differ slightly from those above, but the purpose of each section will usually be as described. Some papers include additional sections or differ from the above outline in one way or another. However, the outline just presented is a good starting point for writing a technical paper.

To write your paper, you should proceed as follows:

Step 1: Start by writing a **complete first draft** of your paper, except for the Introduction and Conclusion. (It is easiest to leave the Introduction and Conclusion until after the main body of the paper is written.) In writing your paper, keep the following in mind:

1. You must always present the *big picture first* and then work towards the details. The other way around will not work. This is especially true in the beginning of Section II, where you are explaining the problem you are studying.
2. If you get stuck and cannot figure out how to explain something, a useful trick is to imagine that you are telling a very good friend what you are working on: just put down the words as you would say them to your friend.

In writing your first draft, do not worry if the wording is not perfect. Polishing the document comes later. When you are finished with your first draft, put it away for a couple of days before you begin Step 2.

Step 2: Make sure the ideas in the paper are **in the right order**. If not, move blocks of the paper around with your text editor until they are. Ask yourself: "Can the reader understand every passage strictly from the material up to that point?" If not, add material or move ideas around. Make sure there are not gaps in your logical arguments, and make sure you are not implicitly assuming that the reader understands something needed to follow your arguments, even though you have not stated it. The reader probably understands less than you think.

Step 3: Work on the **transitions** between ideas. Make sure that at each stage the reader has a *roadmap* of where he or she is going. The reader must be able to see the big picture. At the beginning of each section, make clear to the reader *in advance* what the purpose of that section will be and how that section relates to the preceding material. At the end of each section, you may also want to remind the reader that you have now completed what you set out to do in that *section*. Then point out what the purpose of the next section will be, and so forth. These connecting statements are called *transitions*. The reader must always be able to *see where you are going and why and how far you have progressed*.

Step 4: Check each paragraph for unity. Each paragraph should have one main point. Usually the central point of each paragraph is stated in a topical sentence at the beginning of the paragraph, but not always. You should not mix different ideas together in the same paragraph. If you are having trouble getting a certain section of your paper to sound right, go through that section one paragraph at a time and ask yourself what the main point of each paragraph is. Foggy writing is often due to mixed-up paragraphs.

Step 5: Work on the sentences to reduce the **fog index**. The Fog Index F is defined as $F = 0.4(L + P)$, where L is the *average number of words per sentence and P is the average number of polysyllables per 100 words of text* [1]. (A polysyllable is a word with three or more syllables.) To evaluate the Fog Index for your paper, count the number of words per sentence and the number of polysyllables per 100 words for a representative portion of your paper five or six hundred words long. Ideally, you should strive for a fog index less than 10. In technical writing, it is sometimes difficult to get the Fog Index below 10, but a Fog Index above 15 is a warning that your material will be very hard for a reader to follow.

Consider the following examples taken from typical office memos. Note that both memos say the same thing.

Fog Index = 35: "In order to eliminate the possibility of errors occurring in the time charges relating to engineering jobs through transposition of numbers or typing errors, each of the Division Planning Offices should set up a file of time cards showing all authorized project numbers and make a daily check of the charges on all time sheets forwarded to the Accounting Department to be sure that

only authorized numbers are used." (1 sentence, 69 words, 13 polysyllables)

Fog Index = 11: "It is easy to transpose digits and make typing errors when entering project numbers. We suggest each Division Planning Office set up a file of time cards showing all authorized project numbers. Then all charges should be checked each day before sending time sheets to the Accounting Department." (3 sentences. 48 words, 5 polysyllables)

To reduce the fog index, you must do two things: (1) reduce the length of your sentences (by breaking long sentences into shorter ones), and (2) get rid of as many complicated words as possible (by using simpler words instead).

Step 6: **Get rid of as many passive verbs as possible**. Always check your paper for passive verbs. ("The data were measured and the results were correlated.") Change as many verbs as possible into the active form. ("We measured the data and correlated the results.") Using too many passive verbs makes your writing boring.
Editor's comment: At their worst, passive verbs can make writing incomprehensible. The reader always needs to know who is doing what to whom, and a passive verb often obscures both the agent and the recipient of an action. In Ted's example, the passive form obscures who it was that measured the data and correlated the results.

Step 7: **Use verbs more than nouns**. Do not bury the main action of your sentences in nouns or adjectives. Instead, let the verbs carry the action. Consider these examples:

Example: "The annual report produced a *disappointed* reaction from the sponsor."
Revision: "The annual report *disappointed* the sponsor.
Example: "It is our *expectation* that we will see *radiation* pattern improvement when the antenna is elevated."
Revision: "We *expect* to *improve* the radiation pattern by elevating the antenna."

Your writing will sound better if you move the action into the verbs.

Step 8: **Get rid of as many abstract words as possible**. Your paper will practically always sound better if you use specific words instead of abstract words. For example, instead of "We determined the conditions for performance improvement," say "We measured the noise variance necessary to increase the bit error probability by 5 percent." The problem is that abstract words often convey a different meaning to the reader than the one you intended.

Step 9: **Check for consistent use of verb tense.** Many technical professionals change verb tense frequently between the future and present tense for no reason. You should check that your verb tense is consistent throughout the paper. Usually it is simplest just to stick to the present tense: "We present our results in Section III," instead of "We shall present our results in Section III." (Note that the correct future tense for the first person (I or we) is "shall", not will.")

Step 10: **Do not use "this" as a pronoun**. Avoid sentences such as "This is..." and "This gives..." When "this" is used as a pronoun, its antecedent is often missing or poorly defined, and the resulting writing usually looks amateurish. A typical example in engineering writing is, "By increasing the impedance, the radiation level is increased and the electric field becomes stronger. This means that..." What specifically does "this" refer to? (Moreover, who did the "increasing"?) The solution to this problem is to change "this" to an adjective by inserting a suitable noun. For example, use "This result is..." "This difficulty is due to..." and so forth.

Step 11: Check your entire document for subtle **grammatical mistakes**. We are not talking here about elementary grammar problems. Presumably you do not write egregious sentences such as "He don't got no potatoes." Rather, the idea is to watch out for more subtle problems, which are very common in engineering writing [2]

Step 12: **Polish and polish**. Check that the sentence rhythm and timing are pleasing, and that the ideas flow clearly and simply. If some section does not quite sound right, work on it some more. Eventually you will get the right wording. You are looking for subtle changes that will improve the way the paper "flows." The main tools you should use for this

step are: (1) reducing the Fog Index by shortening sentences and eliminating big words, as discussed in Step 5, and (2) checking each paragraph to make sure it has one main point, as described in Step 4. You will get better at this step over time, as you develop a "feel" for clear writing.

Step 13: **Write the Conclusion**. This Conclusion section should simply summarize for the reader what has been presented in the paper.

Step 14: **Write the Introduction**. The Introduction is frequently the hardest part of the paper to write. It must be smoothly written. The Introduction should address each of the items mentioned in the outline on Page 1. Moreover, the points discussed in Steps 1-13 should all be used to polish your Introduction until it is as smooth as possible.

Notes
The Fog Index was first suggested by Mr. Robert Gunning, an early advocate of clear writing. According to him, the factor 0.4 in the definition makes the Fog Index correspond approximately to the number of years of education a reader must have to read a document easily.