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# The Art of Technical and Scientific Writing

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***Abstract*—In this work we present some guidelines and advices concerning preparation, presentation and writing of scientific and technical texts. Particular attention is given to college level reports. Some principles and effective examples are given.**

**Keywords**: Scientific writing, technical reports, technical presentations.

## I. Introduction

Writing well is hard but necessary. It is not rare for the writing of a report to become the slowest part of a research task. Einstein wrote a lot slower than he thought – a little more than a page a week, when inspired.

Writing is an unloved, even scorned, task by many scientist and engineers that would rather use their time in other activities considered more useful. Nevertheless, it is wrong to think like that: writing is the most efficient way to organize ideas and to communicate them to others. Besides, it helps to order your thought and to build consistent models.

Writing quality is a determinant factor on the impact of the research. After writing it is easier to speak and expose the issue before any audience. Writing serves specially to communicate the results of your work: it may be a technical report, a review text or an article where you describe your discoveries. You may have had a brilliant idea or even performed an excellent work, but if you expose it erratically, writing in a confusing way without any logical chaining, many will not read it to the end but will also be suspicious of the truthfulness of what they have just read.

Hence, all efforts toward a good writing are a handsomely paid endeavor. Nevertheless, writing can be quite frustrating. In order to avoid the frustration, before correcting your article for the thousandth time, you must understand that this task is an important component of your work and should be allotted at least 10 to 20% of the project total time.

I have written this small guide in the hope of helping those who may need to write a technical-scientific work, especially in the undergraduate level. The rules we describe here are the most used in this kind of work but, given the space constraint inherent to an article, we cannot expand and discuss them all thoroughly. The references included at the end of the text will serve as a perfect complement to the information described here.

## II. The Commandments of Scientif Writing

### A. *Be simple without becoming simplistic*

This is the secret of technical writing. The idea of using a obfuscated style including complicated terms and elaborated expressions is appealing to many. We may use it unconsciously, in order to make an impression, in the hope of becoming more serious and more important. Nevertheless, it is a huge mistake! A pompous text is hard to read, annoys the reader and renders the message less understandable.

Writing must be simple, objective and concise: no words in excess, irrelevant expressions, interjections or ramblings. Nevertheless, no important details should be omitted. Among the many possibilities to explain an idea, always choose the simplest. Kill all signs of pomposity (which are, unfortunately, very common in our culture). Resist the temptation of impressing the reader with encyclopedia knowledge. If you want to show your literary skills, then you should write a novel.

Let us analyze the following example:

Incorrect

> *"As it is widely known, nowadays human kind problems keeps on being, as it was in ancient years, to find new energy sources that may attend to its needs. Traditional fuels, besides being pollutant, are limited in their reserves. In this context, natural gas may be seen as one of the most promising forms of energy."*

Better

> *"Given its available reserves, its low price and small amount of pollution, natural gas is nowadays one of the main energy sources that can be considered an alternative to oil."*

### *A. Think about the reader's needs*

When writing, think about your typical reader. Identify what he already knows about the theme and the additional explanations that may be necessary. The goal of technical writing is to explain what the issue is, how and why a solution works, what has been discovered or why the results were (or were not) those expected. Adapt the depth degree and the level of your text to the kind of audience you expect to have.

Unless your audience is composed solely of specialists, never assume that your reader knows everything that you consider basic. If you are in doubt, use the lowest bar. For a generalist reader, avoid technical terms and mathematical expressions. Present only what he needs to know, and not everything you know. Use analogies that can present your message in a context that is familiar to the reader.

If you are writing for a scientific journal in your specialty field, the most important things are the methods and detailed results. Nevertheless, if you are writing for a less specialized journal, you must explain your work further and explore all possible consequences.

If you are writing for a wide circulation paper, you must be able to draw interest from unknowledgeable people. In order to do so, you must refer to high social impact applications as well as using some common strategies, such as stories, humor, analogies with daily phenomena, cartoons and/or attractive figures. Here, imagery and graphical presentation are very important.

For instance, the fact that the Sun produces an amount of power equivalent to $10^{26}$ W may mean nothing for your readers, even if they have good technical knowledge (not to mention those readers not familiar with power notation).

It does not harm to write this number – that may be advisable, for formalism sake. Nevertheless, after writing it, you must put it in perspective explaining, for instance, that this value is so high that the amount of power the Sun produces in a second would satisfy mankind needs for ten thousand years. Even in technical presentations it is always convenient to put matters in a context, especially if they are difficult to understand.

### *B. Create your own style*

The depth of someone's knowledge on something can be evaluated only after this person describes the knowledge with his own words. It is a mistake to try to copy someone's style, no matter how good it may seem to you.

Do not be afraid to write with your own words. Writing well is an art that takes time to perfect, but if you don't try it, you won't nail it. Use words that you know well, that fit into the spirit of the message and that respect the reader's needs.

It is normal for the first draft to come out quite bad with several mistakes in it. Nevertheless, with the help of modern text editors and thorough reviews made either by you or by someone you trust, your work will certainly end up in a format that pleases you.

### *C. Be specific*

Whenever possible, use numbers to make your reasoning more precise: measurements, estimative, statistics, etc. Numbers present information and make the text clearer. Try to avoid terms such as "much", "a lot", "substantial", "considerable". Though they are adequate to language juggling, they should be used sparely inn scientific writing.

Avoid generalities and platitudes, such as "pollution is a threat to the planet cause by mankind". Specify the type of pollution you are referring, present values and compare them with data generated by to other studies.

Be careful with your conclusions – in complex issues, such as the impact of pollution in a ecosystem, it is always very hard to prove cause-effect relationships, even when they seem obvious to us. Don't fall into the temptation of coming to conclusions without being able to prove them empirically. In doubt, be less ambitious and assume more specific conclusions.

Here, you should be as careful as can be. Avoid extreme or biased opinions. If you are in doubt, instead of "everyone", write "almost everyone" or "most". For instance, instead of writing "affluent pollution have damaged the entire Tejo river ecosystem". Say before "in the last three years, the pollution level in the Tejo River has almost tripled and in this time period there was a strong decrease in fish populations that live in this ecosystem. Some of those species, such as the Sável, are probably extinct, and we have not found a single individual". These terms can be used in more generalist presentations, when there is irrefutable proof or the fact has been demonstrated.

Always present clear definitions of the used terms, of the symbols that are inside the equations as well as the precision inherent to each value or the sources where they came from. You must also make it clear what are the foundations of your arguments. If they are incorrect, conclusions may not have any weight. Also make it clear how you got your data and in what conditions and explain the limitations of your work.

Specify the probable sources of error. Whenever possible, quantify them. For instance, do not limit yourself to stating "the room was quite noisy, and this disturbed the experience that measured the sound intensity of a speaker". You should rather state, "as there was a lot of background noise in the lab, we measured the sound value with the speaker off. We verified the average noise value of 50 dB with peak value from 60 dB to 65 dB.

Don't start writing whenever you feel the urge to transmit an idea. Think thoroughly if you have anything important to say: an idea, a successful experiment, an activity report, an opinion. Only write after you have consolidated your knowledge n the issue and possess a well formulated idea on what to write about. Practice the writing because it is a mighty instrument that will help you structure your thought.

You must remember to focus the reader's attention on he relevant aspects, not numb him with an encyclopedic collection of technical data. Avoid at all costs to present more information than the strictly necessary to justify your argument. All remaining data must be referred to an adequate bibliography.

Especially in an oral presentation, your mission is not to tell everything you know, but to captivate your audience. Let the details be revealed by the questions or by the reading of a written article that can be made available through the Internet.

### *D. Attention to the following issues*

• Clarity: clarity of exposition is one of the best criteria to evaluate whether the theme was well understood by the author;
• Objectivity: whenever possible, use numbers to quantify a concept or reinforce an argument. Instead of "many", say exactly how many or present an estimative.
• Completeness: the text must transmit a message completely, that is, must contain everything necessary to be understood. Each sentence must be complete and the arguments must follow an order that leads to the conclusion, without exaggerating in the details.
• Coherence: any assumption, extrapolation or generalization must be based on sufficient evidence. Avoid words that assume as proved that something that is not, such as "obviously", "for sure", "it is clear", etc.
• Honesty: no one can know everything on all subjects, but you must be sure to understand everything you are saying. Do not write something that you don't understand just because it seems important or nice. If you copied it from a text, refer to it explicitly.
• Order: the reader will understand better your message if it is presented in a logical order. Remember that your paper is a tool for communicating ideas and that a large share of your readers will use it to learn more about a specific subject. Therefore, didactic is a fundamental part of your paper (see section III for more details).
• Rigour: avoid errors either technical and ortographic.
• Versatility: do not get conditioned to what you were expecting from the experiment. The assumptions of the theoretical model may not be valid. Never stop trying to explain, or at least fix, a discrepancy between theory and experiments.

### *E. Respect the following rules*

***On form***

• Use active voice. Instead of "the thermometer must be read", prefer "Read the thermometer".
• Write in the present tense. Avoid specially the conditional form.
• Write in positives. Instead of "One cannot expect the temperature increase to have any effect on the measurements", you should prefer "the measurement should be independent from temperatures". Denying a negation has a null logic effect.
• Use specific language. Instead of "a bad wheather ensued", prefer "it rained all week".
• Keep related terms close.
• Be conservative: use a common font, such as "Times New Roman", do not use color, avoid abusing underlining and bold. Do not use uppercase or "cute" fonts. Foreign names and expressions must come either in italics or between quotation marks.
• Avoid parenthesis.
• Prefer short sentences, but avoid writing in a telegraphic style.
• Verb must agree with the subject, no matter which words are between them.

***On content***

• Avoid alliteration;
• Avoid technical jargon and use abbreviations parsimoniously. It is irritating for the reader to find references to abbreviations or terms he does not know.
• Avoid terms in foreign languages if there is a common expression in your language that will render the same effect. For instance, instead of *mutatis mutantis* use "in a similar way".
• Define and explain the meaning of all symbols used, as well as the origin of all equations. Do it immediately after they appear in the text.
• Avoid using unnecessary words and do not be redundant.
• Avoid idioms, platitudes and popular sayings, quotings, generalizations, colloquialisms and rhetorical questions.
• Finally, remember that exaggerations are worse than modesty.

## III. HELP THE READER

### *A. Decide what the reader needs to know.*

Try to know a lot about your readers, especially if they are specialists or the general public. For a more generalist public you must spend a lot of your presentation time in a general overview for them to put your work into context. Sometimes, this requires a radical change to the text.

Consider the following example. In order to present a work for a specialist in astrophysics, we could say "in this work we show that when we remove the restriction of the constant value for the speed of light, we are taken to a new representation of the Lorentz invariant that implies the discretization of time-space in the picture of Einstein equations".

Let us see how this hermetic sentence could be rewritten in order to be understood by the layman: "Einstein's Relativity theory assumes that a ray of light always reaches us at the same speed, no matter the speed we are currently at. Even though this theory was successful, it raises some important difficulties, one of which is to explain why the universe is so universe, knowing that there are regions that could not have interacted since its inception. In this work we show that the hypothesis that the speed of light was higher when the universe began could explain this observation. We will show how this takes us to a new theory, more general than Relativity theory and will study some of its surprising implications".

Adjust the level of detail in the exposition. Sometimes you need to inclusive an exhaustive explanation of everything, but, in most cases, the writing essential is centered in the

foundations of the new things presented, in the interpretation of results and in the conclusions and implications of the work performed.

If you are writing a review article, you must elaborate on all the details on the theme, including a brief historical review. In an investigative work, you must concentrate on the newly discovered issues and refer to literature on everything relevant but already known. If it is a technical report, you must present only the essential on the experience and the results achieved, being careful to verify whether the report is complete. In order to know that, ask yourself the question: "if I give my work to a specialist, would he be able to understand everything I did?"

Never leave unjustified sentences that are not obvious, being careful to define every new term of concept. Help the reader establish a logical rhythm between all sentences, paragraph and sections in your text.

Even though writing should be concise, the understandability of your text must be the supreme criterion. If you need to explain a difficult concept, do not fear to add a paragraph, a section or a concrete example. If you think that something may be unacceptable to the reader, present proofs or results that are enough to justify it. Never assume that your point of view is obvious to others.

### *B. How do I start?*

The first sentences are the most important in your text, whether to guide the reader through the rest of the reading, or to capture his attention. Hence, you must state at first what you did and the conclusions to which you came.

A common trick is the inversion, that is, to present your conclusions in the beginning. Do not waste the first lines: use them to make it clear to the reader what is your most important message, your central ideal or what you discovered, even if you have already done that in the abstract. You will hardly be able to capture the reader's attention by starting to write banalities or following a mere chronological sequence of events or wandering through well established conclusions.

## 2.3 Capture the reader's attention.

A common mistake when writing a technical report is to assume that the reader is interested to read everything he has to say. Do not commit this mistake! Make all necessary efforts to capture the reader's attention and as quickly as you can.

The beginning and ending are the most important points to emphasize in a text. The first and last paragraphs (introduction and conclusions) are the ones that will most probably be read. Inside each paragraph the first and last lines are the most important. Hence, you should not finish your paragraph with expressions, words or interjections that are not necessary. End it with the conclusion of the idea it exposed, even at the risk of repeating yourself.

Inside each phrase, the first and last words are the ones that receive more attention. For instance, if you want to emphasize the word "automatic", instead of writing "we are proposing a method for the automatic analysis of several samples", you should prefer "we propose a method that can analyze several samples automatically" or "an automatic analysis method is proposed to analyze several samples".

Choose a more intense language, using adjectives and more pronounced expressions to support your most important points. Do not disperse the reader's attention with irrelevant details, information that they already know or aspects that re too technical or too formal (for instance, uncertainty analysis). In this last case, put all those topics in an appendix. Focus your text on the message doing whatever possible to keep the reader attentive.

**Table 1:** Avoid the following sentences that could be interpreted as shown.

| **Introductory Sentences** | **Possible Interpretation** |
|---|---|
| As it is widely known | I think |
| It is evident that | I think |
| It also may be true | I don't know what to think |
| Everybody knows that | Some people think that |
| For obvious reasons | I have no proof |
| There is no doubt that | I am convinced that |
| As stated above | This is superfluous |
| A typical example | The most adequate example |
| As far as we know | We may be wrong |
| As we know | We probably don't know |

### *C. Style and Rhythm*

Some scientists wrongly believe that style is not important in technical writing, but it is an integral part of the text. Let us see some important topics on that.

Prefer short sentences. A sentence should not be longer that 20 words because longer sentences make it more difficult to read the text. Nevertheless, do not abuse this idea so that you do not break the reading rhythm. Sometimes a long but well built sentence is superior to several short sentences. For instance, do not write "We cultivated a bacteria culture. We waited 20h. After that period the number of bacteria doubled. All cells died in the next day. The bacteria culture became brown".

The subject of the sentence should be close to the verb without interjections or other elements in the middle. If you intend to say something else, write another sentence. Use few verbs in the same sentence.

Change paragraphs when you change ideas. It is not the aesthetics of the text that commands the inclusion of a paragraph, but yet the need to separate ideas.

Use punctuation to determine the writing rhythm. Do not abuse commas spreading them uniformly through the text as if plowing a field! In order to verify the rhythm of your writing, read it aloud.

Watch out for repetitions and excessive use of adjectives: those do not reinforce the idea you want to transmit, but yet they annoy and confound the reader.

Be consistent with verbal tenses. If you start the report with a verbal tense, you should keep it to the end. In the same way, you should be consistent with the subject: if you start to write in the first person of plural (we), you should not change to the first person of singular (I). Many years ago it was a rule to write all technical text in the first person of plural, even if a single person was the sole author. Nowadays, this rule is in disuse being common the use of "I".

When you are addressing a bigger audience, use original and imaginative sentences. Establish curious analogies and spice the text with some humor. The simples and most effective way to send a message is to tell a story, an anecdote, if possible dramatic, that is in some way related to the theme. For instance, Richard Feynman, when he wanted to explain what happened to the Space Shuttle, used a glass of ice and a piece of rubber. When he put the rubber into the ice, it became less elastic and this way everyone understood that the problem was caused by the loss of elasticity of the Orings of the fuel deposit of the Space Shuttle.

## IV. THE CORRECT USE OF WORDS

Writing is a powerful instrument of persuasion. A coherent message presented in a well written text can have a strong impact on readers. The form in which they are written is as important as the ideas. The choice of words must be careful with the sense as close to the usual as possible. Clarity is the supreme criterion of writing.

### *A. Writing is not the same as speaking*

If you tried to transcribe an oral conversation, even among cultured persons, you rarely would get a good prose. Although the goal is the same, writing is very different from speaking.

In oral language, you can emphasize an idea through repetition or introducing more words than necessary. That is due to the fact that the person we are communicating with is right in front of us and his attention is guaranteed: we can always check whether he is following what we are trying to communicate. In writing, those strategies are forbidden. Here, the emphasis is obtained from the use of adequate wording, punctuation and through the structured organization of paragraphs.

### *B. Words in excess*

Using superfluous words is a much more common mistake than the use of wrong words. Short and concise sentence elucidate the reader while unnecessary words confuse, distract and annoy him. A short sentence must contain only the words that are strictly necessary; each of them with a clear goal, as described in [7].

Use good English, but do not confuse it with "erudite English". As long as text clarity is not compromised, use vernacular expressions to replace overly technical terms. Excessive use of technical jargon tends to hide an inability to communicate or, worse, ignorance.

Nevertheless, use specific terms with well defined meaning in place of vaguer terms. For instance, words like "instinct" and "libido", even though they have a specific meaning, have been so overly used that they became overly vague words and their use should be avoided. Vague terms, used in almost all context, create the illusion of understanding something that we know nothing about.

### *C. "Verborrea"*

Unfortunately, the use of superfluous words, pompous expressions and complicated terms is an habit that has deep roots in scientific culture. Even though it is more common in Law and Economics, this nefarious habit impregnates equally a large number of engineers and scientists.

There are several reasons to write this way. One is the ignorance of the exact meaning of words; the other comes from a confusion of ideas or the mere inability to write correctly. But there are other deeper reasons to put futile words in a text. Some people believe that writing many words is explaining an idea, while others are afraid to write exactly what they thing, and many simply have nothing to say.

"Verborrea" results from an unconscious effort to avoid simplicity, as if the latter would take merit away from the author. The belief that long and difficult words or even Latin expressions confer higher authority and wisdom to the author is deeply rooted in our culture. Foreign words or expressions are pretentiously inserted in the text to confer erudition to it.

"Verborrea" is a plague that makes it difficult to understand the message and created an unnecessary distance between author and read, showing lack of respect with the latter.

### *D. Advices*

- Writing in the positive (prefer likely for not unlikely).
- Avoid using metaphors or other figures of speech.
- Never use a big word when there is a short one that would fit.
- If you think that you can cut a word from the text, do it without thinking twice.
- Avoid the excess of adjectives, such as "very big", "remarkable", "admirable" or "extremely interesting".
- Avoid words such as "really", "obviously", "clearly", "evidently" and "naturally" as well as expressions such as "it is logical" and "it is natural".
- Be reasonable, avoiding positions that are either too strong or extreme.

### *E. Examples of bad writing*

As an example of bad writing, here goes the following text:

> "T*he last years have seen changes in teaching in an unprecedented scale when compared to all previous period in the history of our education. Such advances required a monumental expenditure of*

*money and resources, and it is interesting to realize that in other countries, such as the United States....*"

Mistakes:

- Years do not see.
- "...in any previous period in the history of our education" is a tautology. It should read "in the history of education".
- Changes are later referred as advances.
- Avances do not require.
- Expenses cannot be monumental.
- "it is interesting to realize" is superfluous.
- Is there another country such as the United States?
- The period of time referred is not explicitly mentioned.

## V. How to write a college technical report

In this section I will present some tips on how to write a lab report for college student. This is not a list of rigid rules but only suggestions that I consider to be useful.

### A. Paper description

When writing a report, you must present the following topics:

- Introduction or summary, where you make clear very shortly the goals of your work.
- Exposition of the theoretical concepts of models that will be tested.
- Description of the experimental arragement used: the type of equipment used, referring only to the most important technical aspects (precision, sensitivity, quality and purity of materials, etc).
- Presentation of graphs and tables obtained.
- Calculation of uncertainties.
- Critical analysis of the results and comments.
- Conclusions.

### B. Graphs, figures and tables

Tales help summarize information. They must be explicit, and if possible be interpreted without reading the text. Information contained in tables and graphs should not be repeated in the text. Tables too long should be in an appendix.

Whenever necessary include figures that illustrate some aspect of the work used such as, for instance, the experimental device used. You should worry more about clarity than with the fidelity of the sketch: a simplified sketch with the main components well illustrated is almost always more elucidative than a color photo.

Graphs are a condensed form of presenting several results. Besides, they help the reader understand the concepts better. Think of the best way to present your data and try to concentrate the values in the smaller possible number of figures. However, you should be careful about the cases where you want to focus on a particularly relevant aspect – in this case you should present a separate graph.

You must use a program that creates scientific graphics with acceptable quality. Even though some spreadsheet software, such as Excel, allow you to create graphics, its quality and ease of use are not enough. For those using Windows, the Origin program can be used and in Unix the are the freewares *xmgr* and *gnuplot* – which is harder to use, but very effective. For Windows and DOS environments, there is a very simple and practical software called Easyplot.

The graph axis where the data are presented must always have units. If you cannot present units or if they are irrelevant, explain it in the subtitle. You must explain the meaning of all curves in the own graph or in the subtitle. In order to distinguish several lines you can use dotted or different thickness lines – avoid color, for several readers do not posess color printers.

There are several ways to present experimental points in a graph. The simpler one is a linear graph of the "xy" kind. If you are presenting measurements, then each record corresponds to a point that must be quite readable. You must make all efforts to find the error measurement associated with each measurement. Usually, graphical programs present those errors as vertical lines centered in the point with a laength equal to the double of each value error.

There are several programs that draw automatically smooth lines that pass through all point in the graphic (splines). Be careful to include those lines because usually the have no meaning. In case you want to draw a smooth line you must fit the points. For instance, the linear fitting consists in determining the parameters $a$ and $b$ such that $y(x) = ax + b$. Explain int eh figure that this line is fitted writing in the subtitule the fitting coefficients. If this curve corresponds to an analytical function, then you must make it explicit its mathematical expression in the text or in the subtitle.

Graphs with semi-logarithm scale are used when we are representing variables whose values present variations of several orders. For instance, the number of bacteria in a colony can grow exponentially:

$$N(t) = N_0 e^{at}$$

where $a$ is the growth rate and $t$ is the time. If we apply the logarithm to both sides of the equation we get:

$$\ln(N / N_0) = at\,.$$

If the coordinates axis is logarithmic then we will get a linear graphic. When both axis encompass several orders of magnitude then we should use a graph where both scales are logarithmic.

We also have parametric graphs where $x$ and $y$ are both a function from a single parameter $t$. For instance, the parametric equations of an ellipse are: $x = a \sin(t)$, $y = b \cos(t)$.

In order to represent a function of two variables $f(x,y)$ it is necessary to use a software with tridimensional graphics. You can choose among the following hypothesis:

- Building a tridimensional surface with polygons that adjust continuously;
- Bidimensional representation using level curves or contour graphs;
- Sequence of $yz$ lines for several values of $x$.

Please notice that to transform a set o points $xyz$ into a 3D graph, the program needs to preprocess the data in order to build a continuous smooth curve that passes through all the points.

Notes:

1. Prefer bidimensional graphs because they are easier to read and interpret. Three dimensional graphs are useful when you want to present a more qualitative view of the data.
2. Always prefer graphs in black and white because using colors leads to many problems: after making copies the reader cannot interpret the graph anymore and with the passage of time the colors dim, besides being more expensive to print.
3. Bar or pie graphs are seldom used in scientific and technical communications. Avoid them.
4. Number and write subtitles to all figures (below them) and tables (above them). You must make an effort to help the reader to interpret the figure and/or table without referring to text.

### C. Uncertainties

Any measurement has as associated error. Exact numbers are an abstraction that exists only in textbooks. Reality is always associated with plus or minus "something" that translates our inability to perform the measurement with more rigor. This "something" can mean a precision in the first decimal place or even in the first ten decimal places. There are cases in which the values are so hard to find that we are only left with estimations.

A physical quantity must be written with the number of decimal places equivalent to its precision, never a bigger one. For instance, writing 3,983 means that we have precision is four digits. Hence, writing 1,00 is different from writing 1, for the former means that we have a precision in two more decimal places.

When adding, subtracting, dividing and multiplying two numbers, the result has the precision equivalent to the lowest one of the terms. For instance, when dividing 1,2345/0,10 the result is not 12,345 but yet 12,34.

There are many causes of uncertainty in measurement, such as errors when reading the scale, random and systematic errors.

Error when reading the scale is associated with the measurement equipment and is half of the smaller scale of the measurement instrument.

Systematic error may be related to defects in the equipment or incorrect proceedings performed by the scientist. This type of error must be eliminated verifying carefully all the experimental device.

Random error is due to the fact that there are several factors over which we have no control and that can influence measurements. Its value is estimated by the variance:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \bar{y})^2}{N}}$$

where $y_i$ are the performed measurements, $\bar{y}$ their average value and $N$ is the number of measurements. We can make this number smaller by increasing the number of measurements $N$: to reduce $\sigma$ to half we must quadruple $N$.When working with a small number of measurements (smaller than 30) it is common to use $N-1$ in the denominator instead of $N$.

In most cases we have two measurements ($x$ and $y$) and we want to know the uncertainty associated to a quantity that is a function of these two variables: $f(x,y)$. Its calculation is based on the derivatives rule of a function of many variables. Hence, if we have two measurements $x_0$, and $y_0$ with uncertainties $\Delta x$ and $\Delta y$, the uncertainty of the function is given by:

$$\Delta f(x,y) = \sqrt{\left(\left.\frac{\partial f}{\partial x}\right|_{x_0} \Delta x\right)^2 + \left(\left.\frac{\partial f}{\partial y}\right|_{y_0} \Delta y\right)^2}$$

For instance, imagine that we want to know the uncertainty associated to the function $f(x,y) = x/y^2$ at the point ($x_0$ = 1,75, $y_0$ = 2,3), when we have an uncertainty in both variables given by $\Delta x$ = 0,02 and $\Delta y$ = 0,01. The value is then given by:

$$\Delta f = \sqrt{\left(\frac{1}{2{,}3^2}0{,}02\right)^2 + \left(\frac{2\times 1{,}75}{2{,}3^3}0{,}01\right)^2} = 0{,}01$$

For more information on this specific theme, please refer to the online paper [7].

### D. Analysis of the results

Issues to consider when analyzing the results:

- Present the results in a logical sequence, that not necessary reflects the one that actually happen in the lab.
- The relevant values must not come in the middle of the text, but appear in a graph or table.
- Coment the resuts:
  - Verify that the values found are those expected by theory, within the margin of error.
  - Remember that the experiment is the master of the truth. If the values are different from the ones expected by the theory, one of the situations must have occurred (in order of probability): either you are making one (or several) mistake(s); there is a faulty equipment. The theory is not adequate or you have discovered a new phenomenon.
  - Reference all negative results: if an experiment does not lead to the expected results, present the results and try to find an explanation for this fact.
- If possible, compare your values with other measurements in order to evaluate the consistency of your results.
- Differences that are not statistically relevant should not be described as insignificant. Improbable does not mean impossible.

### E. Conclusions

Write the conclusions in order to help the reader realize the most important things done. That is, the conclusions should

describe the most significative findings of your work. Refer to what you could measure and the results you could (and could not) prove based on the measurements taken. If the results are not conclusive or contradict the expected results, *say it explicitly*.

Propose new explanations or new models, but always use solid and plausible arguments as foundations for your affirmatives.

### *F. Bibliography*

Bibliography appears at the end of your report and must come numbered or ordered either by the moment when the paper is referred in the text or by alphabetical order on the author's names, depending on the standard defined by the vehicle that is going to publish your work. There are several norms that are slightly different, but the most common is the Anglo-Saxon that reads as follows:

- Book: Author, title (italics), editor, city, year. Example: C. Bishop, *Neural Networks*, Oxford University Press, Oxford (1998).
- Article: Author(s), name journal, volume ("bold"), stating page, year (between parenthesis) Example: A. Vieira and C. Fiolhais, Phys. Rev. B, **34**, 1134 (1998).
- Web page: use the complete address Example: http://cfc.fis.uc.pt/roteiro

### *G. Points to review before delivering the report*

- *Print* and read the whole report, if possible, out loud.
- Check for ortographic errors, wrong numbers, formulas or graphs; did you forget to make a reference to something important?
- Did you understand everything you wrote?
- The introduction explains correctly what was done in the paper?
- Cut mercilessly all sentences and words superfluous – verify this imagining how intelligible the text would be without them.
- Each section and paragraph is relevant and is in the correct position?
- Are all subjects presented in an ordered and clear sequence?
- Do the results make sense? Did you comment them?
- Are the conclusions supported by the results?
- Are there any references lacking? Are they all correct?

### *H. Writing of units and equations*

- Leave a space between the numerical value and the corresponding unit (50 W).
- Do not use a point after the unit unless it is the end of a sentence.
- In the Portuguese and French systems the comma separates units from decimals, while in the Anglo-Saxon, the separation is made by the point. Please notice that in the latter case the comma is used to separate the units from the thousands.
- Never add an *s* to a symbol (m means either meter or meters).
- Do not leave a space between the prefix and the symbol (ms = millisecond)
- Vectorial amounts are represented in italic bold font (force = $\boldsymbol{F}$), or with an arrow above it ( $\vec{F}$ ).
- Symbols and mathematical expressions must be written in italics, except the functions: sin($x$).
- Number and units are written in normal style.
- Centralize and number the equations at the right.
- If possible, present all numbers with the same precision,.

## CONCLUSION

This paper intended to show the importance of writing in the creation and presentation of works of technical and scientific nature. We showed that the writing must be an integral part of the effort developed by the student or researcher so that his work can be better accepted by the scientific community and have the expected impact. We approached several language, form, style and content issues in order to make the presentation clearer, more logical and more understandable. The concepts present were consolidated through several presented examples.

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