

# Template for scientific writing in the nano-electronic and solid-state lab courses

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Scientific writing is a prerequisite for publishing any physical results in experiment and theory. This is a guideline for writing a publication of the experimental results achieved during the nano-electronic and solid-state lab course courses at the RWTH Aachen, University. The style of academic writing, citing, formatting equations and the correct usage of tables and figures is presented. This paper together with other sources mentioned will help the participants to write up their results in a scientific publication style.

## I. INTRODUCTION

This template explains scientific writing and is mainly a translation from the “Template für Kurzveröffentlichungen im Praktikum” by Ines Lammertz, which is used for the lab courses in the Bachelor lab course. Some regulations are adapted for the English publication styles. The style used here belongs to the journals of the American Physical Society. It is probable that the lab course participants will write their first publication for such a journal and thus can apply their gained experience directly. In addition to this paper the participants should refer to the file “apssamp.pdf” and its source code “apssamp.tex”, which are the official example files from the American Physical Society. They can be used to extract the TEX commands for all regular style elements e.g. small figures, wide figures, appendix, labeling, multiline equations, wide equations etc. Finally, a paper published in Physical Review A [1], one of the journals of the American Physical Society journals, is attached to give an example for the structure of a paper. Participants can use this to learn what content should be covered and in which order.

The publication should be written as if the experiment was invented and designed by the participants, who now want to publish their results. The instructions of the experiments can be used as a reference. Also the participants should think about why their paper is an important scientific contribution and motivate the paper accordingly.

This paper is organized as follows: Section II gives advice on how to start with a publication. Section III explains how to formulate the content in the scientifically correct way and section IV introduces the structure that should be used. Section V covers the correct usage of Figures and Tables and section VI correct equation formatting. Finally citations are explained in section VII.

## II. THE HARDEST PART IS GETTING STARTED

At the first attempt nobody writes a perfect text, because writing is always an iterative process: writing, reading, feedback, editing, reading, feedback... This cycle continues until the work is completed successfully. It is therefore not only legitimate, but even useful to start by formulating a rough draft containing the important information, ideas or arguments. When writing the draft, one should not search too hard for the “perfect” word or particularly smooth phrases. The first important point is to roughly get your thoughts down on paper. If this is successful, you can begin the revision of your work. Highlighting preliminary formulations is useful, in order to find better formulations later on.

Is the text structured logically? Do the transitions between the individual text elements make sense? Does the reader get all the information he or she needs to follow the argument? Does the text contain redundant information that can be deleted? Are all the quotes correct? Has the original question been answered? Are the section titles adjusted to the content?

Bearing these points in mind, you should critically examine your own text. The revision of a scientific text should be done in three steps:

- Check content and arguments
- Check for language errors (wording, punctuation, etc.)
- Check the form (font size, quotes, etc.)

The following section gives some tips for the revision of academic texts.

## III. ACADEMIC STYLE

When is a text a good text? Scientific writing does not mean expressing yourself in as complicated a way as possible. It is important to present work in a precise, objective, understandable but above all accurate manner.

A perfect academic text does not contain unimportant information. On the contrary, nothing can be omitted. Words such as “now”, “pure”, “but”, “novel” can usually be deleted without changing the meaning of the content.

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The same applies to the terms “well”, “actually”, “as it were”, “after all”, “in any event”, “by no means”, “ultimately”, “that is”, “very”, “extremely” and “totally”. Furthermore, vague claims such as “much”, “little”, “intense”, “enormous” etc., should be avoided [2, pp 138]. “A sharp drop in voltage has been perceived.” What exactly does this mean? Does it mean a decrease of  $40 \times 10^3 \text{ V}$  to  $20 \times 10^3 \text{ V}$  or  $0.6 \text{ V}$  to  $0.1 \text{ V}$ ?

One can also omit phrases which merely announce what will be discussed more closely further on: “In the following the inductance should be defined.” It is better to formulate the definition right away. Writing accurately also means avoiding ambiguities. Connections between sentences (e.g. when using pronouns) must always be clear in scientific texts.

“Two is better than one,” does not hold true for scientific texts. It is not the goal to write as many words as possible, but to formulate soundly. One should avoid duplicating information. Beginnings of sentences like “In this experiment ...” should be avoided in a publication. They correspond to the style of a test report, but are rather uncommon in publications.

A precise style is also important in the formulation of headings. Here two fundamental points should be kept in mind:

1. Say a lot with a minimum of words: Headings should be short, but concise.
2. Make a statement: “theory part” for example, is not a meaningful heading. Better would be “Theoretical foundations on the photoelectric effect”.

In scientific texts the person who produced the results is typically not of interest. (“I measured the resistance.”) It is only important that the resistance was measured. Who has done this is beside the point. The use of the passive helps denote the essentials: “The resistance was measured.” In English in contrast to German, however, active sentences can be used to avoid complicated grammatical constructions and to write densely.

One can save a lot of frustration by choosing a meaningful writing order. The writing sequence denotes the temporal order in which the sections of the text should be written. This does not necessarily correspond to the order of the sections in the final text. The following writing order has proved useful:

- Main part
- Introduction
- Conclusion
- Abstract

#### IV. STRUCTURE OF CONTENT

Any text needs a theme that guides the reader from first to last. Such a story line is important to ensure that

the work is understandable and easily readable. It is useful to begin the text with a short abstract as displayed in Fig. 1. The abstract is a very compact, and not necessarily chronological, summary of the entire work. It provides one sentence of motivation, information about the problem and the goal of the work, the theoretical framework, the data collected, the methods used and it outlines the most important results. The final sentence states why the work is important for the future. Since the abstract summarizes the complete work, it should be the last part to write. The abstract is different from the summary of the work in it contains no quotes.

If the abstract provokes initial interest in the scientific reader, they are more likely to continue reading with the introduction. Therefore, the introduction is the flagship of the publication. It presents the reader with the motivation (“Why is it important to do research on this topic”), the well-referenced state-of-the art (“What has been done before?”), and the problems investigated in the main part (“What does this work add to the field of research?”). For long publication is common to end the introduction with a short outline of the main part.

The subsequent main part of the paper deals with the problem-oriented discussion of the issue. It can be based on specialized literature to, but also on your own data from the lab course. It is important that (I) description of the experiment and applied methods, (II) data analysis and (III) discussion of the results are strictly separated. The issue at hand must be accurately, correctly and comprehensibly described. Only then can one evaluate, analyze or interpret the problem. Note that any claim must be verifiable, accountable and objective. Technical terms, words or abbreviations must always be explained or defined: “The heterostructure forms a two-dimensional electron gas (2DEG). The carrier density in the 2DEG is measured by...”

The text concludes with a summary which not only refers back to the initial question, but also gives an outlook on follow up questions. All data necessary for understanding the text must be presented in the paper. This includes the specification of measurement uncertainties, both as a numerical value and in the form of error bars in charts. This means that the main data must be carefully selected and presented. In the discussion metrics and measurement uncertainties must be taken into account. Otherwise it would be, for example, impossible to compare two values. For example:

- Literature value of  $15 \text{ V}$
- 1st measurement:  $(16 \pm 2) \text{ V}$
- 2nd measurement:  $(14 \pm 0.5) \text{ V}$

Neglecting the measurement uncertainties, one might conclude that both measurements are equally good, since both differ by  $1 \text{ V}$  from the literature value. While the deviation from the literature value for the first measurement is covered by the measurement uncertainty, the literature value is not within the measurement uncertainty

interval of the second measurement. The conclusion that both results are equally good, would thus be wrong here.

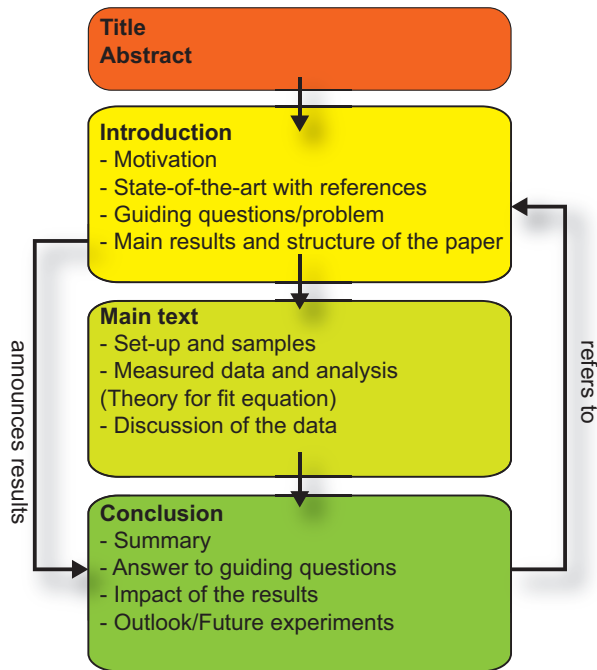


FIG. 1. Structure of a scientific paper. The story line of scientific paper develops from the introduction via the main text to the conclusion. Introduction and conclusion set the frame of the work.

## V. A FIGURE IS WORTH A THOUSAND WORDS... A TABLE AS WELL

Figures in a text can attract potential readers, although their primary goal is to facilitate the reader's understanding. Therefore, it is necessary to provide each figure with a suitable caption, which must contain sufficient detail that the reader can understand the figure content in principle, without having to read the text. It is common to start the caption with a short title e.g. "Scanning electron micrographs." continued by the details in full sentences. If a figure consists of several panels e.g. "(a), (b), (c)..." each panel has to be explained in the caption in consecutive order. Every figure (and all its panels) must be referenced in the main text. If the figure consists of a graph, the main text should highlight the important features and give an interpretation afterwards. The figures should be numbered consecutively.

The values recorded during the experiment can be clearly and compactly presented in tables. You should, however, note some basic things: It must be made clear what is written in each cell of the table. Therefore, each column (or where appropriate row) requires a heading. In the lab course this heading usually contains the physical variable and unit, e.g. " $U$  in V" or " $U$  (V)". Note that round brackets are typically used to mark a unit in

English in contrast to square brackets in German. When entering measured values, it is not reasonable to fill a cell with an endless sequence of digits. The entries have to be rounded to significant digits within the measurement accuracy. It might be useful to add a column with the associated measurement uncertainties of the measured values. Tables like figures require a caption, which has to be sufficiently detailed to allow the reader to understand the content without the main text i.e. all variables used in the Figure or Table has to be defined in the caption. Tables are consecutively numbered, but independent from the figure numbering. Tab. I lists the caption formats for Figures and Tables. Depending on the origin of a Figure or Table an attribution has to be added at the end of their caption.

## VI. EQUATIONS IN SCIENTIFIC PUBLICATIONS

Sooner or later writing about physics requires the use of equations or symbols in a publication. When dealing with these following rules can help: Symbols representing numbers are set in italic and (abbreviated) names in normal font.

Examples:

- $n$  times ( $n$  can be any number)
- 2-fold degeneracy (a fixed meaning)
- $f(x)$  (a function with variable meaning)
- sin, cos, tan (the name of a trigonometric functions)

Italics are also selected for symbols of physical quantities, but the associated units, the normal font is selected, for example,  $U$  (voltage) - V (volts),  $I$  (current) - A (ampere) or  $T$  (temperature) - K (Kelvin).

Between a numerical value and the associated unit use a space or half-space e.g. 19 V. The numerical value must not be separated from the unit by a line break. You can use the keyboard shortcut Control + Shift + Spaces instead of a normal space in Word or  $19\sim\text{V}$  and  $19\backslash,\text{V}$  for an unbreakable full and half space in TEX, respectively. Equations are usually presented in a separate line and numbered consecutively like pictures and tables. Short equations can be shown in the text. It is required to define all abbreviations, constants and variables:

For example: "This is Ohm's Law

$$U = R \cdot I, \quad (1)$$

where  $U$  is the voltage,  $I$  the current and  $R$  is the resistance which is to be experimentally determined ."

## VII. CORRECT CITATION

The purpose of proper citation is to enable readers to look up and verify statements you have made. It is also to

TABLE I. Captions formats for Figures and Tables vary depending upon their origin. A figure or table should be first mentioned in the text and listed thereafter.

Origin of Table or Figure	Caption format
Fig. or Tab. copied unchanged	Fig. x/Table x: Title. Description in full sentences (from Ref. [x])
Fig. or Tab. slightly changed	Fig. x/Table x: Title. Description in full sentences (after Ref. [x])
Tab. showing own measured data	Table x: Title. Description in full sentences
Fig. showing own measured data	Fig. x: Title. Description in full sentences

allow you to give correct credit to other authors. “Plagiarism is not only a direct quote without quotation marks, but also an indirect quotation, which gives the impression that it derives from the author’s own knowledge.” [3, pp 116]. Thus, using synonyms or changing the word order does not makes someone else’s idea your own idea! To avoid plagiarism one has to make everything recognizable which does not result from one’s own thoughts and to provide the proper sources. One refers to the source by a number of the source given in the bibliography. The number can be either given in square brackets or by a superscript number. If another paper from a journal is cited one has to provide author’s names, journal, volume, page and year in the bibliography e.g. “Daniel Loss and David P. DiVincenzo, Phys. Rev. A **57**, 120 (1998)” [1]. Some journals also require the title of the cited publication. A direct quote in a text has to begin and end with

a quotation mark. Quotation marks in the original text are substituted by single quotes (‘...’) [3, pp 118] or visa versa. In analogous quotations no quotation marks are used. If a “foreign idea” is presented, its’ nature and scope must be clearly marked and it has to be clearly separated from the author’s own ideas. The original, intended sense of the original author may not be altered in any case!

## VIII. CONCLUSION

In this template basic information on how to write a scientific text was provided. Hopefully it will ease the writing of the lab course results in a paper format and will help the reader to write his or her publications scientifically and successfully in the future.

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- [1] D. Loss and D. P. DiVincenzo, Phys. Rev. A **57**, 120 (1998).  
[2] A. Preißner, *Wissenschaftliches Arbeiten: Internet nutzen, Text erstellen, Überblick behalten* (Oldenbourg, München, 2012).

- [3] M. Karmasin and R. Ribing, *Die Gestaltung wissenschaftlicher Arbeiten* (Facultas Verlags- und Buchhandels AG, Wien, 2011).