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Guide for Writing Technical Reports

For Final Year Projects and Postgraduate Studies
in Engineering

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Fifth Edition (revision 4)

2021

saam vorentoe • masiye phambili • forward together

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Abstract

This guide provides guidelines to engineering students for writing technical reports (for example on vacation work, experiments, design projects and final year projects), theses and dissertations. It provides a discussion of the contents of the various main elements of a technical report and gives the recommended format. Some of the important elements of a good microstructure and style, and practical guidelines for the compilation of a technical report, are also provided. The guide concludes with a checklist that can be used by students to eliminate general mistakes. The appendices provide guidelines for documenting experiments, designs, calculations, thesis proposals, the use of SI units and the use of the Harvard referencing method.

Acknowledgements

The authors thank Thomas Harms, Nico Theron and Mimi Westdyk for helping to improve the guide and Anneke Louw for the layout and formatting of the first edition.

The third and later editions include an appendix on plagiarism and the use of the alphabetic referencing style that was contributed by the Language Centre at Stellenbosch University.

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1 Introduction

The majority of engineering tasks include the writing of technical reports, even if the main objective is much more extensive. Since technical reports and papers are used to summarise information in a way that is easily accessible, they should be as concise, accurate and complete as possible, and be aimed at a specific group of readers.

The immediate objective of this guide is to help students following bachelor's, master's and doctoral programmes in engineering to approach report writing effectively during their studies and to present the reports in a professional format. A further objective is to prepare students for the writing of technical reports and papers in engineering practice. The format described in this guide is the prescribed format for student reports in the Department of Mechanical and Mechatronic Engineering at Stellenbosch University.

In this document, the term "reports" is considered to include theses and dissertations.

The emphasis in this guide falls on the prescribed format for a technical report, but a few hints on paragraph structure and writing method are also given. Although there are a number of standard formats, such as those of Beer and McMurrey (1997), Campbell and Ballou (1994) and Blicq (1987), only one format is described in this guide. Readers who would like to obtain more information on the writing of technical reports are referred to the books by Weisman (1974), Pakin (1982), Michaelson (1984), Pauley and Riordan (1985), Rathbone (1988) and Van Emden (1989). There is an excellent book on style written by Strunk and White (1979).

The format of this guide follows its own prescriptions as far as possible to serve as an example.

2 The Process for Compiling a Technical Report

As with any writing, one of the first questions that must be asked in the planning process is "Who is the target reader?" In engineering practice, the reader can be a client, a colleague, a manager or a junior. In academic writing, the target reader is usually the examiner. The examiner is normally independent and was not involved in the initiation or executing of the work being reported. The author must therefore ensure that sufficient background and detail is given to convince the examiner.

When academic writing is aimed at an examination process, the outcomes or assessment criteria must be thoroughly accounted for in the planning of the writing. It will be of great benefit to the author to study the relevant assessment criteria.

The process of writing a technical report begins with planning the work on which the report is based. Even at this early stage, the task can be broken down into elements which are likely to become the chapters or sections of the report. The final sequence of the chapters and sections will usually not correspond with the order in which the work was done, but will be determined by the desired structure of the report.

The general rule is to begin writing the sections of the report as soon as possible. The table of contents should be drafted very early in the process of writing the report since the table of contents provides a good overview of the entire document and, while the report is being written, provides an indication of which sections still need to be done.

Regardless of the order of the report, a chapter or an appendix (with tables and figures) should be written as soon as that part of the work has been completed, for example when some apparatus has been developed or set up, a section of theory has been derived, a computer program has been written, or a set of readings has been taken. It is also a good idea to give the written work to a fellow student or a supervisor as early as possible to criticize constructively. Some sections written as appendices in the early phases will remain appendices, while others will later be included in the main text and some will not be included in the final report.

It is important to keep in mind that report writing is an integral part of the thought process: it helps to define and order ideas and to derive well-considered conclusions so that further planning of the work can be undertaken.

3 External Structure

Professional technical reports are characterised by a scientific approach, typical external structure and formal style. This chapter discusses the recommended external structure and the way in which the scientific approach is reflected in this structure.

3.1 Sequence of Main Sections

The elements of a technical report, in their prescribed sequence, are:

- Cover page

- Title page

Abstract
Dedication
Acknowledgements
Table of contents
List of tables
List of figures
Nomenclature
Introductory chapters(s)
Central chapters
Conclusions
References
Bibliography
Appendices

The external structure does not only relate to the sequence of the elements, but also to the relationships between the elements and the importance and size of each. It is important that the emphasis be placed on the central chapters. A report is like a story: it must have a beginning, a middle and an end, but the middle is the actual story. The introduction must not be too long, and the central chapters must not be overpowered by the appendices. The conclusions should follow from the central chapters in a justifiable manner. In other words, the central chapters must present a systematic argument that leads to the conclusions.

The elements of a technical report are discussed separately below.

3.2 Cover Page

A cover page is only required for a printed document and not for electronic documents (e.g. in pdf format).

The purpose of the cover page is to protect and identify the report. It must contain the title, the initials and surnames of the authors, the date, the name of the department and university, and the emblem of the university.

The title of the report must be considered carefully. A good title is striking and clearly reflects the contents of the report. A few guidelines for the selection of titles are the following:

- Think about the reader's first impression.
- Include important and distinguishing key words, for example the words that somebody will use in a literature search.
- Leave out any words that are not essential. Avoid meaningless expressions, such as "A Theoretical and Experimental Study of...", or longwinded

descriptions, such as “Concise Practical Guide for the Writing of Technical Reports and Papers”. Every word must count.

3.3 Title Page

The title page contains all the information given on the cover page, but, in the case of paper documents, the logo and footer are not repeated on the title page. For electronic documents (e.g. in pdf format), the logo and footer should be retained. Further, both paper and electronic formats, the status of the report (terms of reference) must be included, for example “Experimental Techniques Report: Project 1” or “Mechatronic Project 478 Final Report”. If an individual project is done under the guidance of a lecturer (for example a final year project or thesis), the supervisor must also be indicated, for example “Supervisor: Prof PJ Erens”.

3.4 Abstract

A short summary or abstract of 100 to 150 words must appear on the second page of the report. It must summarise the contents and most important findings so that the reader can decide whether he/she wants to read the rest of the report. A few guidelines for the abstract are given below:

- The abstract is not an introduction to the report. It often provides no background information.
- Every word is important. Limit the use of words that do not convey important information to a minimum, for example, do not say things such as “In this report, the failings of a compost turner are investigated”, but rather say “The failings of a compost turner are investigated”.
- Convey the key elements of the objective and context, and the most important methods, findings and recommendations.
- The abstract is usually the last part of the report to be written.
- Include in the abstract the keywords that someone may use to search for the report in a literature database.

In certain technical environments, an Executive Summary is given instead of an ordinary abstract. Executive summaries must be brief, but can be more than one page long, and provide sufficient quantitative information so that a manager can identify the most important decisions arising from the report and grasp their extent and impact.

3.5 Dedication

This is a short sentence, in the middle of a separate page, in which the report is dedicated to a family member, friend or acquaintance. It may be left out and is seldom included in short technical reports. It is more suited to theses.

3.6 Acknowledgements

In this section, other people or organisations that were directly involved in the execution, presentation and financing of the project or report are acknowledged, such as technicians, typists and institutions that provided money or made facilities available.

3.7 Table of Contents

The table of contents must begin on a new page. The page is provided with a heading, such as “Contents” or “Table of Contents”, followed by a list of the three main levels of headings and their page numbers. Journal papers do not have a table of contents.

Regarding the front matter, two approaches are acceptable: In the first approach, all the headings of the front matter are included in the table of contents (e.g. Abstract, Dedication and Acknowledgement are included, with their page numbers). The Table of Contents heading will normally not be included in the table of contents itself. In the second approach, the first item in the table of contents is the first heading that appears after the table of contents, for example List of Figures. In the second approach, therefore, front matter that precede the table of contents are not listed, but front matter that follow after the table of contents are listed.

Appendices must be listed in the table of contents, each with their title and starting page.

3.8 List of Tables and List of Figures

These lists, arranged according to the table and figure number, each begin on a new page and indicate the relevant page number in the right-hand column. The titles of tables and figures must be descriptive enough so that a specific figure or table can be identified in the list and must correspond to the title used for the figure or table in the text.

3.9 Nomenclature

The list of the symbols that are used must begin on a new page. The list is arranged in the following sequence: All the ordinary symbols are listed first,

followed by the superscripts and then the subscripts. Finally, the auxiliary symbols, for example overbar and underscore for vectors and averages or accent marks for time-dependent components, are listed. The following order must be used within each of these groups:

- Firstly all the Roman letters (in alphabetical order, with the capital letter of each symbol before the small letter, for example “A” followed by “a”, followed by “B”);
- Then all the Greek symbols (in the order of the Greek alphabet, capital letters before small letters);
- Finally, the symbols that begin with numbers, in numerical order.

Units should preferably not be given in the nomenclature section, as the symbol represents a physical property that is independent of the system of units. If units are given, it should be indicated that the units are "typical units".

In a short document that contains only a few equations and symbols, the nomenclature section may be omitted, as long as the symbols are explained in the text. Symbols should not be explained in both the text and the nomenclature.

A consistent set of symbols should be used (for example do not use V, C and W for velocity, unless there is a consistent difference, such as V for relative flow velocity, C for absolute flow velocity and W for blade velocity). If equations are taken from sources that use other symbols, the symbols should be “translated” into the set that has been selected for the report.

3.10 Introduction

The introductory chapter or chapters should provide the reader with the following information:

- The context in which the report originated, i.e. the work from which it originated, how it links to/differs from preceding or related work, the limitations that were placed on the work (as a result of external circumstances or through own choice), and so forth;
- The purpose of the report, i.e. the problem that was examined and the specific objectives of the work;
- The motivation for the work or report, that is, why the work was undertaken.

A good strategy to describe the background is to use the "funnel principle": start by describing the broad background ("big picture") and gradually move to the more specific context of the report. If it is relevant, the introduction will contain a general overview of previous work in the field and definitions of words or

expressions that have a specific meaning in the document. An overview of the rest of the report is sometimes also provided.

In long reports, such as theses, the aforementioned content can be spread across more than one introductory chapter, but it should be kept in mind that the objectives of the work should be readily recognisable.

Particular care should be taken when formulating the objectives. The objectives should be stated in such a way that the Conclusions section can answer the following question "Has the objectives been reached?" The objectives should be distinct from the strategy to achieve the objectives, unless the evaluation of the success of a specific strategy is in itself an objective.

3.11 Central Chapters

The structure of the central chapters depends on the contents of the report. Typical contents of the central chapters for various cases (for example design reports, experimental reports, etc.) are given in the appendices.

The following are general guidelines for the central chapters:

- Every chapter should be focused on one topic, i.e. it should have a clear purpose. The title of the chapter normally reflects the purpose.
- The contents of the central chapters must remain strictly linked to the purpose of the report. Contents that are only of marginal importance should preferably be placed in the appendices.
- The following structure of chapters or within chapters can usually be followed and corresponds to a scientific approach:
 - Introduction: the purpose of the chapter, and how it links to the purpose of the report;
 - Underlying or simplified assumptions;
 - Analytical or numerical theory used, or the procedure for the investigation;
 - Measured results, results of the analysis or observations (verifiable results);
 - Processing of results: method and answers (objective);
 - Interpretation of results (subjective, but critical and well motivated);
 - Conclusions: usefulness and importance of results; how the results contribute to achieving the purpose of the report.
- The central chapters do not usually follow the chronological sequence of the project.
- A consequence of the scientific approach is that each statement must satisfy one of the following:
 - The statement is obviously true.
 - The statement is proven in the report.
 - The statement is motivated in the report.

- A reference to a source that has made the statement before is given with the statement.
- Each conclusion drawn in the conclusions must be corroborated in the central chapters.

3.12 Tables and Figures

This section focuses on the editorial and layout aspects of tables and figures, but starts with a few general guidelines for their use. More detailed guidance on the way to represent information in graphs is given in Appendix G.

Tables are used for quantitative comparisons, when the differences between lines on a graph will be too small, or when the relationship between the dependent and independent variables is not clear. Figures (drawings, sketches, graphs and photos) can usually be more easily interpreted by the reader than tables and are therefore preferable when the more qualitative nature suffices.

The following are general guidelines for both tables and figures:

- Each table and figure must have both a number and a caption. Figures are numbered as a single series and tables as another. The number of the chapter or paragraph can be used in the table or figure number (for example Table 2.1 or Table 3, and Figure 1.1 or Figure 2).
- Table captions are placed above the table and those for figures are placed below them.
- The text of the report must refer to each table and figure, but the text in the body of the report (i.e. the part from the introduction to the conclusions) should only in exceptional cases refer directly to figures or tables in the appendices.
- Tables and figures in the main text must be placed on the page where the first reference is made to it, or as soon as sensibly possible thereafter.
- If the layout of the table or figure is such that it needs to be rotated to fit on the page, the bottom of the table or figure must be placed on the right-hand side of the page.
- Tables and figures in the main text must be separated from the text by at least 2 open lines above and below the table or figure.
- A capital letter must always be used when a specific table or figure is being referred to, such as Table 2 and Figure 5. The abbreviation “Fig.” may be used in the caption of the figure.
- The text in the tables and the writing in the figures must not be smaller than 3 mm, and preferably similar to that of the report's text.

- It is a good idea to repeat the data used for all the graphs in the report, in tabular form in an appendix, for future use.

The following are general guidelines for the tables:

- Each column, and sometimes also every row, must have a title, with units if applicable.
- Tables in the main text usually do not have more than a few rows because they otherwise contain too much information and can impede the comfortable reading of the report. Larger tables should rather be included in appendices.

The following are general guidelines for graphs:

- The axes of a graph must be named in words, in conjunction with units.

3.13 Conclusions

The purpose of this section is to make it clear to what extent the purpose of the report was achieved and which findings were made. All statements in the Conclusions must be supported in the report.

Guidelines for the contents are:

- Summarise the purpose of and motivation for the document/project.
- Clarify to what extent the purpose was achieved. Provide a summary of each section of the report to indicate how that section contributed to the attainment of the purpose. Also summarise the most important findings, methods or techniques.
- Discuss the implications of the findings and indicate the contributions made by the report. Emphasise the most important findings.
- Provide suggestions for further work, if appropriate.

3.14 References

The references section is normally placed at the end of the main report, just before the appendices if there are appendices. In the past, the references section was sometimes placed after the appendices, at the end of the document, but that practice is now rare.

The purpose of references is to indicate the origin of statements that are not general knowledge in the field (such as Newton's laws, the laws of thermodynamics or the Bernoulli flow equation), to acknowledge the work of others, and to provide additional information for readers who might be interested in obtaining further information.

No references may be included in the list of references to which you have not referred in the report, and vice versa.

There are various methods of referencing, although only one alphabetical and one numerical system are discussed here. Each system consists of two parts: the reference in the text, and the reference in the list of references. Unless other instructions have been given for the specific report, the alphabetical system must be used.

3.14.1 The alphabetical system

Appendix F gives an excellent summary of the topic of references and examples of applying the alphabetical system.

An important advantage of the alphabetical system is that the references are completely independent of one another: any one can be taken out or added without influencing the others. This is particularly useful when new references come to light while a report is being compiled. Furthermore, readers who are familiar with the literature can often recognise the names of the authors in the text.

3.14.2 The numerical system

In this system, references in the text are indicated by numbers (in the order of their first appearance) in square brackets and in the list of references they are arranged numerically. In other words, the first source referred to in the report, is [1] and the second is [2], without regard for the names of the authors or the date of publication. In the list of references, the references are listed in numerical order, but formulated similarly to the method used in the alphabetical system, except that each reference begins with its number and the year of publication is placed just before the page numbers or, if there are no page numbers, at the end of the reference.

3.15 Bibliography

In some schools of thought, a bibliography is a list of sources, usually books, that provide a broad background on the topic, but to which no specific reference is made. Only comprehensive technical reports and books have such bibliographies. It is rarely seen in engineering students' writing.

However, other schools of thought apply the term "Bibliography" to what is referred to above as the "References".

3.16 Appendices

Detail that disturbs the flow of the main text, and particularly detail that does not form an integral part of the main text, must preferably be provided in the

appendices. Examples of this are complicated technical derivations, detailed descriptions of apparatus, computer programs, lists of unprocessed data, sample calculations and concise commercial information (data sheets).

Just as in a chapter, every appendix must have a descriptive title.

The appendices are numbered “Appendix A”, “Appendix B”, etc. Examples of numbering are: page numbers “B1”, Table A1, Figure C2. In shorter reports, the page numbers of the appendices can follow on from those of the main report.

References in the appendices refer to the list of references at the end of the report, unless the appendix has its own separate list of references.

4 Microstructure

The previous chapter discusses the macrostructure, i.e. the typical sequence of the main elements of a technical report, but the structure of a report goes much deeper. Every chapter, and even every paragraph, also has a structure. Just as the report must have an introduction, central chapters and a conclusion, each chapter must have an introductory section, a central section and a conclusion. Even a paragraph can have an introductory sentence, a central section and a concluding sentence, although the structure of paragraphs can be more varied. Furthermore, just as the entire report has a central purpose or theme, a chapter and a paragraph should also have a specific purpose.

Paragraph structure is a specialised topic in its own right and cannot be completely dealt with in this report. De Stadler (undated c) provides a good, concise discussion. Only a few guidelines for paragraphs and sentences are given here:

- A paragraph should not be longer than 10 lines, because readers seldom read long paragraphs.
- It is usually a good idea to begin a paragraph with a theme sentence or to place the theme sentence prominently. The theme sentence states the purpose or theme of a paragraph.
- It is possible to distinguish between different types of paragraphs in terms of their purpose, for example the introductory paragraph, the explanatory paragraph, the linking paragraph and the concluding paragraph.
- The consecutive sentences of a paragraph, as well as the phrases in a sentence, must be linked to one another. A communal purpose or argument is a prerequisite for coherence. Markers (i.e. words that indicate the direction in which an argument is moving) play a very important role in this regard. Examples of markers are “except for”, “therefore”, “for example”, etc.

- Place the main idea of a sentence in the main phrase.

A continuous theme in good report writing is to always approach the report from the point of view of the reader (De Stadler, undated b). The person who writes the report must therefore continuously ask how a reader will understand what he or she reads in the report. However, it is very difficult for writers with little experience to notice their own mistakes.

The consultation service offered by the Writing Laboratory of the University's Language Centre is the ideal opportunity for students to learn how to write reports with a good microstructure early in their careers.

5 Style

A characteristic aspect of technical reports is formal and concise language use. As in the case of microstructure, style is a wide-ranging and complicated topic. Readers are encouraged to study sources such as that by Strunk and White (1979). Some of the important guidelines for style in technical reports are:

- Only use the third person. If unavoidable, the authors can be referred to as "the authors".
- Each sentence must be a complete sentence, i.e. must contain at least a subject and a verb, and often also an object.
- Do not link two sentences by means of a comma. Use commas sparingly.
- Active sentence construction is usually more striking than the passive construction.
- Use the present tense for something that is still valid, but the past tense for something that happened in the past or is no longer valid.
- Use the right word, not its second cousin (Mark Twain). This statement is of particular importance in relation to technical terminology. The reader's confidence in the technical ability of the author will be greatly impaired if the author does not use the correct terms.
- Sweeping statements must be avoided, since they indicate that the author is uncertain or not knowledgeable.
- Waffling and irrelevant appendices are not at all permissible. The reader's time is precious and, the thicker the report, the less positive his/her initial attitude will be to the report. De Stadler (undated a) provides a few guidelines for maintaining the correct information density in a text.
- It is important that the author keep the reader and his/her interests in mind. Remember, engineers are interested in results, not excuses: what was done,

how was it done, and what does it mean? Nevertheless, it sometimes is necessary to briefly mention the problems that were experienced and the methods that did not work, but only if this will prevent the mistakes from being repeated. When in doubt, leave it out.

- The technical level of the language used must be adapted to the target reader. The target reader of undergraduate reports is a final year student in Mechanical or Mechatronic Engineering at another university.
- Avoid the extremes of banal expressions and pompousness.
- A writing style in which the author gives his/her reader instructions, for example “Add eq. (3) and (4)” should be avoided.
- Explain less known abbreviations, for example “Coherent Anti-Stokes Raman Spectroscopy (CARS)” when they are used for the first time.
- Common abbreviations should preferably be written out (“for example” rather than “e.g.”).
- Bulleted lists are seldom used in technical reports. They may only be used when all the items in a list are of equal importance and when the sequence is not important.

6 Layout

6.1 Margins, Fonts, Page Numbering and Headings

Table 1 and Table 2 give the particulars of a widely accepted formatting scheme for technical reports. Draft reports may alternatively be printed at one-and-a-half spacing on A4 paper with margins of at least 25 mm.

The pages of the chapters and appendices must be numbered in the centre at the bottom using Arabic numerals (1, 2, ...). The start of Chapter 1 (usually the Introduction) must be page 1. Pages before this are numbered in small Roman numerals (i, ii, iii, iv, ...), with the Abstract on page i.

The format for the headings of chapters, sections and subsections must be as in this report. Every attempt should be made to avoid requiring more than three levels of headings. Note that the main text of a report may not be in more than one type of font and the headings should all be in the same font, although the headings' font may be different from the text. Furthermore, it is very important that the layout throughout the report must consistently remain the same, for example with regard to the use of capital letters in the headings and spacing between paragraphs.

Table 1: Acceptable Page Layouts

Paper size	Margins	
	L/R [mm]	T/B [mm]
A4	35/35	26/44
A5	17/17	22/22

Table 2: Acceptable Letter Sizes and Line Spacing

Font	Paper size	Letter height* [pt]	Line spacing* [pt]
Times Roman	A4	12	single or 14
	A5	10	single or 12
Arial	A4	11	single or 14,4
	A5	9	single or 11,8
Computer modern	A4	12	single or 14
	A5	10	single or 12
Charter	A4	11	single or 13,6
	A5	9	single or 11,1
Calibri (Body), Cambria (Headings)	A4	12	single or 14
	A5	10	single or 12

* Headings may be larger, but not smaller

6.2 Equations

Equations must be numbered sequentially, either 1, 2 ..., or per chapter 1.1, 1.2 ... and 2.1, 2.2 The second method makes it easier to write chapters independently of one another.

With regard to the formatting of equations the rest of this section is not applicable if typesetting programs, such as LaTeX, are used for word processing, as these programs format equations automatically.

The two acceptable formats for equations are illustrated in the next two equations:

$$A/b = x^2/(u + v)^{0.5} \quad (1)$$

$$\frac{A}{b} = \frac{x^2}{(u + v)^{1/2}} \quad (2)$$

Occasionally long equations are more easily dealt with by dividing them up, for example:

$$A = x^2 \quad (3)$$

$$b = (u+v)^{0.5} \quad (4)$$

$$y = A/b \quad (5)$$

Note that the letters representing variables or constants must be in italics (sometimes symbols representing matrices and vectors are not in italics, but bold), while functions (such as the trigonometric functions) and units must not be in italics, as in the following examples:

$$x = \cos \theta \quad (6)$$

$$g = 9,81 \text{ m/s}^2 \quad (7)$$

$$a_i = \omega^2 R_i \quad (8)$$

$$\alpha_1 = 20 \text{ rad/s} \quad (9)$$

In equation (8), the subscript *i* is also a variable and therefore is written in italics, while the subscript 1 in equation (9) is not a symbol, and is therefore not written in italics.

A space should be left between parameters that are multiplied (to create a space in Microsoft Equation Editor, hold "Ctrl" down when pressing the space bar), as shown in equation (10). An "x" should not be used for a normal multiplication, since it can be confused with a symbol or the cross product operator.

$$Nu = C Re^n Pr^{1/3} \quad (10)$$

All equations must be indented by at least 10 mm. It is often neater when all the "=" signs on a page are placed below one another, although a large number of successive equations that each consist of more than one line look better if they begin the same distance from the left. A space must be left on either side of each "=".

7 A Checklist

A few questions to be answered while the report is being finalised, follows:

1. Does the report clearly and unambiguously state what you wanted to say? If not, rewrite it before going any further.
2. Do the conclusions follow from the central chapters?
3. Is the structure correct? Are the important aspects given sufficient emphasis? Are unimportant aspects emphasised too much?
4. Is each chapter, section, paragraph, phrase and word necessary? Can it be shortened or improved? Is it in the correct place? (Word processors are wonderful tools with which to make changes.) Can the figures be better combined?
5. Is the transition between chapters and sections logical?
6. Does the report contain all the prescribed elements and do they follow the prescribed sequence?
7. Are the title of the report and headings of the chapters, sections, figures and tables short, striking and to the point? Is the use of capital letters in the titles consistent?
8. Do the table of contents and lists of tables and figures correspond to the headings in the text and of the tables and figures? Word processors can be used to set these up automatically.
9. Have the axes of all the graphs been correctly named, and their units given? Are there units in the column headings of the tables?
10. Does the abstract state how the project originated or why it was done, what was intended, how it was done and what was found?
11. Is the list of references written according to the prescribed format? Are all in-text references included in the References section, and all references in the References section cited in the text?

8 Conclusion

This guide discusses the format for a technical report that is prescribed by the Department of Mechanical and Mechatronic Engineering and provides helpful hints on the structure and compilation of a report. The external structure was discussed in detail and a few guidelines were provided for the microstructure, style and editing.

Students who follow the guidelines in this report will soon be able to compile professional technical reports.

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Appendix A: Guidelines for the Documentation of Experiments

A.1. Principles

Reproducible experimental results are one of the foundations of a scientific approach. The point of departure for the documentation of experiments is therefore that all information required for precisely repeating the experiment, must be provided. Such a large amount of detail is, however, typically only recorded in internal laboratory reports. Reduced information on the experiment itself will be included in most other reports. A good guideline is that, in all cases, sufficient information is provided to prove that the experimental results are credible. In documents such as theses, the theoretical foundations of the experiments must also be discussed.

The following sections provide an extensive list of topics that must be considered for inclusion in a report. The nature of the experiment and the purpose of the report will determine which are appropriate.

Note that the measured and processed results must be clearly distinguished from interpretations and conclusions. The former are usually objective and cannot be questioned (except possibly in terms of accuracy), while the latter are subjective.

A.2. Introduction or Introductory Chapters

- The purpose of the experiment;
- How the experiment contributes to the objectives of the project/thesis;
- The actual situation that is being simulated in the experiment;
- The physical properties that are being investigated;
- Simplifications made or approaches used to approximate the actual situation;
- Theoretical motivation;
- Identification of independent and dependent parameters;
- Known analytical solutions of similar cases;
- Dimensional analyses;
- Order of magnitude analyses.

A.3. Experimental Setup

- Drawings of purpose-built apparatus, including:
 - Detailed dimensions;
 - Schematic layout drawings;
 - Positions of measuring points;
 - The parts of the environment that could have an influence on the results.

- Complete specifications for the equipment used, including:
 - Manufacturer, model no., series no.;
 - Settings for the equipment used;
 - Calibration certificates with dates and the person or organisation that carried out the calibration.
- Documentation of own calibrations.

A.4. Experimental Procedure

- Preparations;
- Sequence in which independent variables were adjusted;
- Warming up or time for stabilisation after change;
- Sequence and frequency of measurements;
- Provision for determining repeatability and accuracy;
- Zero measurements before and after runs.

A.5. Measured Results

- Complete raw data:
 - Sometimes included in an appendix, attachment, separate report or on CD;
 - Units must be documented;
 - Distinguish between set, chosen or measured;
 - Environmental conditions.
- Estimation of the accuracy, reproducibility and resolution of measurements.

A.6. Processed Results

- Explain the statistical processing, for example how averages were calculated, and whether there were outliers and what was done with them.
- Complete sample calculations must be provided, usually in an appendix. Remember that the number of significant digits in the calculations must correspond to the accuracy of the measurements.
- Comparison between data sets and/or with the theory.

A.7. Interpretations and Conclusions

- Interpretation of the results. This is usually subjective. The credibility of the results must be evaluated critically.
- Comparison with theoretical or other published data.
- Discussion of the implications of the results (the "so what"): emphasise the most important results, point out unexpected results.

Appendix B: Guidelines for the Documentation of Designs

B.1. Purpose and Principles

Professional accountability plays an important role in the compilation of design reports. The document must indicate that the engineer carried out the design with the appropriate care and judgement. The information in the report must therefore be such that a third party can review and evaluate the design.

Furthermore, the main purpose of a design must be reflected in the report, viz. that the needs of the clients were interpreted correctly and that the chosen design meets the needs.

Another purpose of a design report is that it can serve as the basis for later changes or improvements to the product. The report should enable the engineers who undertake any further development to avoid repetition of the design work previously done.

The following sections provide guidelines for the contents of design reports. All the aspects will be present in most design reports, although the level of detail will be determined by the circumstances.

B.2. Assignment and Background

- The designer's assignment. All the relevant clients must be identified.
- The scope/boundaries/extent of the project. Interfaces with other projects.
- Time framework.
- Design team.

B.3. Requirements

- The requirements (engineering requirements or design specifications) that the product had to satisfy. This can be stated in term of functional requirements, constraints and using performance metrics with target values.
- A derivation of the design requirements from the needs of the client (for example by QFD).
- Comparison with competing products.

B.4. Concept Development

- Describe the concept generation approach which must ensure that all reasonable concepts were considered.
- Evaluate the concepts using only the design requirements identified above.

- Provide a well-motivated elimination and selection of concepts. Discuss the most important selection factors and, if relevant, why other “obvious” concepts were not selected.
- Describe the selected concept in terms of function and layout.

B.5. Analysis and/or Testing of Performance

- Prove that **all** the engineering requirements were met.
- For each aspect:
 - Explain the aspect that is to be considered, e.g. a physical description of a part and the failure modes that will be analysed;
 - Explain all assumptions, simplifications and approaches;
 - Use explanatory sketches (indicate the notations on these);
 - Provide the analysis or describe the test, as well as the results.
- State conclusions explicitly, in other words, do the analysis or test indicate that the requirement was met?
- Also follow the guidelines for the documentation of calculations, which are given in another appendix.

B.6. Technical Definition of Product

- Provide a complete description, for example set of assembly and detail drawings with bills of materials.
- Provide a precise description or specification of bought out components or subsystems, including the supplier, catalogue number and main dimensions or main performance parameters (for example 3 kW induction motor).
- Provide instructions for the entire life cycle of the product, for example assembly, maintenance and disassembly.

Appendix C: Guidelines for the Documentation of Derivations and Calculations

C.1. Introduction

Only a few broad guidelines are provided here. There are a number of books on the subject, for example Gillman, L “Writing Mathematics Well, A Manual for Authors”, The Mathematical Association of America, 1987.

C.2. Nomenclature

- List all symbols and their specific meaning. If necessary, refer to a figure that illustrates the symbol.
- Be consistent when using symbols: use the same symbol everywhere for the same variable, even if it comes from different sources.
- Use symbols that are commonly used.
- Eliminate unnecessary symbols. Nomenclature must make it easier for the reader!

C.3. Sample Calculations

- Repetitive instances: Show one calculation in its entirety, and only the input values and answers for the rest.
- If own computer programs or spreadsheet calculations were used, provide all equations and a sample calculation. If iterated, only show the final iteration.
- If software applications (such as FEM or CFD) were used, provide the complete input values and options that were used. Provide sample calculations of a simple, relevant case, as well as a comparison with analytical results, to demonstrate that the software was used correctly.
- Explain how the results were interpreted.

C.4. Paragraphing

- Keep the reader informed about what the calculation or derivation is aiming at and what route is being followed: before the calculation begins, explain what is being aimed at and fill in words between the equations that describe the route and why it is being followed (for example “To eliminate β , substitute (2.3) into (2.5)”). Provide direction-indicating words, for example “If” or “then the dynamic pressure can be expressed as follows:”.
- State the conclusion explicitly after the calculation, for example “The calculated safety factor is lower than the selected limit”.

- Equations must form part of the sentence. Symbols represent a word or a phrase and must fit into the flow of the sentence, for example “=” represents “is equal to”, or “which is equal to”.
- Use normal punctuation if the equation forms part of the sentence. If the placing of a full stop after an equation becomes confusing, change the structure of the sentence.
- Do not begin a sentence with a symbol.
- Put spaces before and after “=”, as well as between letters that represent different parameters. Do not use a full stop (“.”) or an “x” to indicate multiplication, unless it refers to a dot product or cross product in vector algebra.

C.5. Layout of Equations and Numerical Values

- Every equation can be numbered or, alternatively, only the last one in a derivation.
- Use a consistent numbering style, for example 1, 2, 3, ... (one series throughout the entire report or appendix) or 1.1, 3.1., 3.2, ...
- The number of the equation must be placed on the right-hand margin (use a right tab).
- Start 10-15 mm from the left margin.
- Place all “=” signs underneath one another if the equations are short enough.
- Calculations: First give the equation in symbols, then with the values substituted, and then the answer (WITH THE UNITS). Leave out the other intermediate steps.
- Derivations: State the assumptions expressly, say when previous equations are substituted and only show the most important intermediate steps.
- The number of digits must ALWAYS be in proportion to the accuracy. The number 2,13242 implies a precision of 0,001%!
- Provide a unit for each number, except inside equations.
- Use the technically correct and generally used forms of units, for example mm AND NOT cm, and stress in MPa or 10^6 Pa.
- Use SI wherever possible (see other appendix for guidelines).

C.6. Traceability

- Provide the sources of each equation, unless it is general knowledge. If conservation laws are used, only provide their name, for example “Energy conservation gives the following:”.
- Provide the sources of all material properties.

Appendix D: Guidelines for Thesis Proposals

D.1. Planning

The particular content of a thesis proposal depends to a large extent on the thesis topic. There are, however, general principles that all thesis proposals must satisfy, and these are outlined in this appendix. The main focus here is on M-theses, but this appendix is also largely applicable to PhD dissertations. The latter must, however, always contain the element of original research too.

While writing a thesis proposal, it is important to consider what outcomes that are generally expected of a thesis. Below are some guidelines that examiners use when they evaluate theses:

Scope: The subject should be suitable for a thesis in the sense that it should be confined to an appropriate field, and should be narrow enough to allow the candidate to develop sufficient depth of understanding in at least a couple of areas.

Objectives: The thesis should have clearly stated research questions or objectives. More information about this is given in the relevant section below.

Logical approach: There should be a logical approach to, or methodology for, addressing the objectives or central research questions of the thesis. This should be evident from:

- The literature review, which should specifically look for answers to the questions or ways to approach the questions;
- The analytical or numerical approach;
- The experimental set-up, if applicable.

Data evaluation and interpretation: The thesis should demonstrate the ability of the candidate to evaluate and interpret data, whether cited, measured, calculated or deduced. The evaluation culminates in the conclusion section, which should refer back to the objectives.

Presentation: The thesis should be presented clearly in the appropriate form and style, whether written, tabular or graphical.

Mastery (Command): While a master's thesis does not have to be original, in the sense that it should be a new contribution to existing knowledge, it should still show the student's familiarity with and command of existing published work, methodologies and techniques where appropriate.

D.2. Front Matter

The cover page should follow the general guidelines given in this guide. The title page should mention, as the terms of reference, that the document is a thesis proposal, the degree it is aimed at, and the name(s) of the supervisor(s).

A thesis proposal should contain an abstract and a table of contents, but other sections found in the front matter of longer reports or theses, are normally omitted.

D.3. Introduction

The introduction should address most of the issues described in the relevant section of this guide, but aspects addressed in greater detail later in the proposal (for example literature) should only be highlighted in the introduction. Typical topics include:

Background: The discipline (for example fluid dynamics), application area (for example axial flow compressors) and importance should be mentioned, for example "Flow in the endwall region of axial compressors plays a critical part in the performance and stability of axial flow compressors".

General objective of thesis, for example "To better understand the effect of endwall flows on the performance of axial flow compressors".

Previous studies: Previous studies, both by the author's immediate predecessors and in the literature, should be outlined. The literature review will not be complete at this stage but the preliminary review must be reported. This review must lead up to the reason why the proposed research is worthwhile.

D.4. Problem Statement, Objectives or Hypothesis

The objectives of the research must be very clearly stated. The objectives should be formulated in such a way that the reader can decide, after reading the thesis, whether the objectives have been met. The objectives therefore have to be measurable in some sense, even though not necessarily quantitatively.

The objectives of a research project can often be stated in terms of a hypothesis that is to be proved. The remainder of the thesis proposal can then outline how the research will test the hypothesis by trying to prove and disprove it (both are required to test a hypothesis).

Another approach to stating the objectives is to formulate research questions, i.e. formulate the objectives in terms of questions to be answered.

Note that each proposal will normally have either a statement of measurable objectives, or the formulation of a hypothesis, or a set of research questions, and not all three.

As with any project, it is important to clearly identify the bounds or scope of the research. The limitations to the investigation imposed by time, financial and other constraints, and in terms of discipline and application areas, must be described.

Common errors in this section are that strategies to achieve the objectives or motivations for the objectives are mixed with a description of the objectives themselves. Unless an assessment of a specific strategy to achieve an objective is an objective in its own right, strategies should be addressed in the Research Planning section.

D.5. Motivation, Background and Literature Survey

This section may precede the description of the objectives, if more appropriate for the specific topic. Some of the issues considered in this section may also have been outlined in the proposal's introduction, but they must be covered in depth here. Depending on the extent of the discussions, Motivation, Background and Literature Survey could each be placed in its own chapter in the proposal.

This section describes the context within which the research is being done. This includes the background to the research (what has already been done by others or is in progress in other research) and motivation for doing the research (i.e. explaining why it is worth doing, and what contribution it will make).

In a thesis proposal it is very important to explain how the proposed research relates to what other researchers have already done: how will the proposed research differ from published work or what will be repeated for confirmation. In reviewing literature, it is very important to integrate the information from different sources, and not to discuss it source by source. A good approach is to identify a number of "issues" in literature that relate to the proposed research, and then consider what each source has contributed to each issue. A discussion structured around a series of issues will help to integrate the various contributions, allowing contrasts or contradictions to be highlighted and discussed. Particularly when conflicting information is given by different sources, the thesis proposal must indicate how the contradiction will be resolved, for example by presenting arguments as to why the one point of view is selected above the other or by including a further investigation of the issue in the thesis research.

D.6. Research Planning

The approaches that will be used to achieve the objectives, test the hypothesis (prove and disprove) or answer the research questions must be explained. The approaches may include experimental investigations, numerical simulations and/or analysis from first principles. Invariably, the results obtained from these approaches will have to be interpreted. The research planning should clearly show how the different "tools" will be applied and how that application will help to achieve the objectives. Remember that the research must enable firm conclusions to be drawn at the end of the thesis research. A critical evaluation of the capabilities, as well as limitations, of each part of the strategy will demonstrate a maturity of judgement.

In scientific work, the quality of the experiment determines the authority of the results. Careful consideration of the capabilities and limitations of each strategy is therefore essential. In this context, "experiment" is taken in its widest meaning: it may include a numerical simulation or even a statistical analysis of samples.

The chapters about research planning should include a discussion of the various experiments that are planned, the simplifications and limitations of each one, and the conclusions that are expected from each experiment. The planning should include estimating the time and resources required for setting up and conducting each experiment. The type of data or information that will be acquired during the experiment must be clearly identified, and the time and resources required for analysing the data estimated.

Ample provision must be made in the planning for the formal "writing up" of the thesis. A guideline for the time required is one to two hours per page for writing up after the work being documented, has been completed.

D.7. Conclusion

The proposal should conclude with a clear statement of the main contributions that the thesis can be expected to make to the body of scientific knowledge: What will someone who has read and understood the thesis be able to do with the knowledge and insights? At this stage the contributions will still be vague, but they should refer back to the objectives and research questions.

Appendix E: Guidelines for the Use of SI Units

E.1. Introduction

South Africa changed to the use of SI units in the 1960s. This system is generally used in Europe and increasingly in North America. The following references are valuable:

- The International System of Units, 7th ed, 1988.
- SABS M33a, The International Metric System.
- Els, DNJ, 2003, Guide for the Use for the International System of Units, Dept of Mechanical Engineering, Stellenbosch University.

A few guidelines for the elimination of common mistakes are given in this appendix.

E.2. Writing Style

- SI units are written in normal letters (not *italics*).
- Abbreviations: lower case letters, unless derived from a proper name. No full stop after the abbreviation, unless at the end of a sentence.
- Written in full: lower case letters, unless the first word in a sentence.
- No plurals.
- Combination of abbreviations:
 - N m or N·m (space or half-high dot)
 - m/s or m·s⁻¹
 - m·kg/(s³·A) or m·kg·s⁻³·A⁻¹
- Prefixes: become part of the symbol (MJ kg⁻¹) and are never used on their own (correct: 10⁶/m³; incorrect: M/m³).
- Leave a space between the number and the unit, for example 3,4 km and not 3,4km. The space should be a "hard" space, that is a space that is not stretched by line justification. In MS Word, a hard space is entered by typing Ctrl-Shift-Spacebar.

E.3. Basic Units, Prefixes and Derived Units

- The SI has 6 basic units: metre, kilogram, second, ampere, degrees kelvin and candela.
- The following are the preferential prefixes in SABS M33a: tera (T), giga (G), mega (M), kilo (k), milli (m), micro (μ), nano (n), pico (p), femto (f) and atto (a)

- Derived units that are permitted by SI:

plane angle	radian	rad
solid angle	steradian	sr
frequency	hertz	Hz
force	newton	N
stress, pressure	pascal	Pa
energy, work	joule	J
power	watt	W
electrical charge or flux	coulomb	C
magnetic flux	weber	Wb
electrical potential	volt	V
electrical resistance	ohm	Ω
inductance	henry	H
capacitance	farad	F
conductance	siemens	S
magnetic induction	tesla	T
luminous flux	lumen	lm
illumination	lux	lx

- Non-SI units that are accepted for use together with SI units:

minute	min	60 s
hour	h	
day	d	
degree	$^{\circ}$	$(\pi/180)$ rad
minute	'	$(1/60)^{\circ}$
second	"	$(1/3600)^{\circ}$
litre	L	10^{-3} m^3
metric ton	t	1000 kg

TAKE NOTE: the abbreviation for litre used now is a capital L, and no longer the cursive lower case letter.

E.4. Decimal Point or Comma?

SABS M33a prescribes that the decimal comma must be used, and a small space between thousands, for example 123 456,23. However, in many international journals, the use of a decimal point is prescribed. Both formats are therefore acceptable in engineering reports. However, consistency is always required, that is, within a given report, either the decimal point or the decimal comma must be used consistently.

Appendix F: Referencing and Plagiarism

This appendix is included by permission of the Language Centre at Stellenbosch University and is subject to copyright.

F.1. What is meant by *referencing*?

- Referencing means that you give credit to the various sources you have used when writing your assignment/report.
- References are cited in the text itself (the so-called in-text references) and at the end in a section called "Reference list" or "Sources used"
- The in-text reference must be cited in the text where you have referred to the specific source. This citation can be given directly where the reference is made or at the end of the sentence, paragraph or direct quotation.

F.2. When should you give a reference?

- When you quote an author's words directly
- When you use somebody else's tables, figures and/or diagrams
- When you put an author's words in your own words (paraphrase)
- When you summarise an author's ideas (summary)

F.3. When is a reference not needed?

You do not need to reference if you consider the information or viewpoints that you give to be general knowledge.

How do you define general knowledge?

- If the same information appears in several sources (at least 5) without any references
- If you think that the information is something that your reader will know in any case
- If you think that your reader will easily be able to find the information in a general information source

F.4. Why should you give references?

- Avoid plagiarism
- Give credibility to your work

- Acknowledge the authors or sources on which you have based your research/arguments
- Help your readers to find the articles, books or electronic sources that you have used
- Show your reader that you have read extensively on the subject of your text
- Show that your research is up to date

F.5. How do you reference?

There are several standard methods of referencing. It is quite common that organisations, scientific journals and even the different departments in an engineering faculty each follow different methods and rules for referencing. It is your responsibility to find out which referencing method is required/applied by your organisation/department or the scientific journal for which you are writing.

Usually one of two types of referencing methods is used, namely either an alphabetic system or a numbering system.

In the alphabetic system the various references are listed alphabetically according to author in the reference list at the end of the document. In the text itself, the author's/authors' last name(s) and the date of the publication are cited in the text where the reference is made. This means that you can add or take out references without influencing other references. The Harvard-system works according to this principle.

In the numerical system (such as the Vancouver-system) the references in the list at the end are given in a numbered list in the order in which they appear in the text for the first time. In the text itself a reference would then be cited in the form of a number (usually in square brackets).

F.6. The Harvard-method of referencing

The Harvard-method of referencing was developed in the USA in the 1950's – initially for the natural sciences but its use has grown in popularity and it is the house style for a number of scientific journals.

The Harvard system is easy to use, both for writers and readers. References are listed alphabetically according to authors in the reference list and the various sources are (usually) cited in the text itself by referring to the author and the date of publication every time that you refer to that specific source.

F.7. Steps for referencing

1. Write down the complete biographical data for any source when you use it for the first time.
 - If it is a book: author/editor, year of publication, title, edition, volume number, place of publication and publisher (This information are usually found on the front and back of the title page – not all of these details will necessarily be applicable for every source)
 - If it is a journal article: author of the article, year of publication, title of the article, title of the journal, volume and issue number of the journal and the page numbers.
 - If it electronic information: in addition to the above also the date on which you accessed the information, the name of the database or the web address (URL)
2. Insert the citation in the appropriate place in your text (in-text reference): use the author's last name followed by the year of publication and in some cases also the specific pages where the reference can be found.
3. Include in the reference list at the end of your document all the references that you have used in your text. The reference list includes only the books, articles, etc. that are cited in the text – if you have used other sources but do not refer to them in your text you can put these in a separate bibliography. The reference list is arranged alphabetically by author. When an item has no author it is cited by its title, and ordered in the reference list alphabetically by the first significant word of the title.

F.8. Examples of references according to the Harvard-method

<i>Journals</i>	<i>In-text citation</i>	<i>Reference list</i>
Article	As discussed by Winsor (1988: 101) ...	Winsor, D.A. 1988. Communication failures contributing to the Challenger accident: an example for technical communicators. <i>IEEE Transactions on Professional Communication</i> 31.3: 101-107.
Article – no author	It is a growing problem in the United States (Anorexia nervosa, 1987: 53) ...	Anorexia nervosa. 1987. <i>American Medical Journal</i> 3.2: 53.
Newspaper or popular	(Venter, 2004: 10)	Venter, I. 2004. Fierce auto rivals make space for collaboration. <i>Creamer Media's</i>

magazine		<i>Engineering News</i> , 3-9 December: 10.
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WWW	In-text citation	Reference list
Document on WWW with author	The communication skills of engineers are as important today as ever (Norback <i>et al.</i> 2001).	Norback, JS, Llewellyn, DC & Hardin, JR. 2001. <i>Shop talk 101. Integrating workplace communication into undergraduate engineering curricula</i> [Online]. Available: http://www.lionhrtpub.com/orms/orms-8-01/norback.html . [2005, Augustus 31].
Document on WWW without author	(Guidelines for using charts and graphs, [S.a.])	<i>Guidelines for using charts and graphs.</i> [S.a.]. [Online]. Available: http://sandhills.edu/english/wordguide/chartadvice.html . [2005, August 30].

Personal communication	In-text citation	Reference list
Interview	... investigated the method (Smith, 2005).	Smith, G.J. 2005. Personal interview. 31 August, Stellenbosch.
Letter	... was satisfied with the results (Robertson, 2005).	Robertson, A.C. 2005. Correspondence. 1 September, Cape Town.

Books	In-text citation	Reference list
One author	The method was already discussed before (Swart, 1997: 58). OR R.P. Swart (1997:58) has already discussed the method...	Swart, R.P. 1997. <i>Materials Processing Technology</i> . New York: McGraw Hill.
Two authors	(Smith & Carpenter 1995: 36) OF Smith en Carpenter (1995: 36) discuss it in detail ...	Smith, A.D. & Carpenter, C.P. 1995. <i>Tool quality and tool life</i> . 2de uitgawe. London: Longman.
More than two authors	(Houp <i>et al.</i> 1998: 56)	Houp, K.W., Pearsall, T.E. & Tebeaux, E. 1998. <i>Reporting technical information</i> . Boston, etc: Allyn and Bacon.

No author	This was apparently not the case before 1995 (Advertising in the Western Cape, 1990:14)...	<i>Advertising in the Western Cape</i> . 1990. Cape Town: ABC Publishers.
Editor	(Anderson 1993: 73)	Anderson, P.K. (ed.). 1993. <i>Encyclopaedia of renewable energy</i> . San Francisco: Pegasus.
Encyclopaedia or dictionary	According to <i>The new James's encyclopaedia for fighting ships</i> (2001: 45) the ...	<i>The new James's encyclopaedia for fighting ships</i> . 2001. London. Prentice Hall.
Article or chapter in a book	As discussed by Baxter (2004: 101) ...	Baxter, M.M. 2004. Tool wear monitoring in C. Carter & B. Smith (eds.) <i>Dynamics of stable turning</i> . New York: MacMillan. 223-230.

Notes

Date of publication: When no date of publication is given, use the abbreviation "s.a." (sine anno = without year) in Afrikaans and in English.

Edition: When the publication is a further or revised edition indicate it with "Revised" or "2nd edition".

It is important to be consistent when you write your in-text citations and your reference list. For example, when you use a comma between the author's name and the date in your in-text citation, continue doing so for the rest of the document.

F.9. What is plagiarism?

Plagiarism can be defined as follows: To use another person's words or ideas as if they were your own.

The following are seen as plagiarism:

- To steal or borrow another person's work
- To pay another person to write your assignment
- To copy directly from a source without referencing the original source
- To use another person's ideas and build on them without giving credit to the original ideas
- To paraphrase another person's work word for word
- To present false data (fabricated, altered or borrowed without permission)

The worst form of plagiarism is to do it intentionally: to pretend that another person's work is your own; to buy a piece of written work from somebody (for example from the Internet) or to pay somebody to write your assignment for you; or to write something word-for-word from a source without acknowledging that source (or to "cut and paste" from the Internet).

But plagiarism can also occur unintentionally: when you rewrite another person's ideas or words in your own words or use small sections of another person's writings without acknowledging it as a source.

Appendix G: Guidelines for Graphs

Graphs are commonly used in technical reports to show trends and relationships. They can convey a wealth of information in a compact and easily understandable format. However, as with all parts of a technical document, care must be taken when using graphs to convey information as precisely as possible. It is therefore very important to take some fundamental aspects of graphs into account. This appendix gives guidelines for the correct use of graphs. It should be noted that the default settings in some commonly used software (like Excel) are usually incorrect for scientific graphs.

In this appendix, for brevity, y is used to refer to the property represented by the vertical axis, and x for the horizontal axis.

One of the most important aspects of graphs is whether the data should be displayed using markers, lines and/or other symbols. Sections G.1 to G.3 give guidelines for determining whether a representation is appropriate for the type of data displayed. The last section gives guidelines for other aspects of graphs.

G.1. Markers and Bar Charts

Discrete markers, such as dots, crosses, etc., are used to show discrete data points, for example data measured or observed at discrete intervals. An example is shown in Figure G.1. Where-ever appropriate, error bars should be shown with markers (see section G.3) to show the accuracy or uncertainty of the data.

A linear or logarithmic x -axis should only be used if the x -property is continuous, such as mass, speed, etc., even if the data was only sampled at discrete values. Bar graphs are only appropriate when the horizontal axis represents discrete values or non-numerical properties. Figure G.2 gives an example.

G.2. Lines and Curves

Straight lines or curves should be used to show continuous relationships.

Lines should rarely be used to join measured data points, since the measured points normally contain errors which should not be transferred to the lines. It is usually more appropriate to fit a continuous relationship (for example a straight line, quadratic polynomial or exponential function) to approximate the experimental data and then plotting that relationship (as shown in Figure G.1). The legend, an annotation or the text of the report must explain what the precise meaning is of what was plotted and, if applicable, how the continuous relationship was obtained.

An exception to the previous guideline is, for example, when there are so many data point that the markers will obscure neighbouring data points. In such cases drawing straight lines between data points, without markers, may be appropriate. Again it is important in such cases to explain the meaning of the graph in the text.

The type of function used to fit curves to discrete measurements must also be chosen with care. In engineering, the ideal is to use a physical or mathematical model of what was measured to determine the type of function. For example, experience has shown that for low Mach numbers and high Reynolds numbers, pressure drop in a duct is proportional to velocity squared. Physics also show that the pressure drop should be zero when the velocity is zero. One would therefore fit the function $y = C x^2$ to measurements of pressure drop vs velocity. High order polynomials will be used very rarely since they do not occur in physical laws. However, an example where a high-order polynomial may be appropriate is where fitting a curve through high accuracy physical property data (for example c_p vs T).

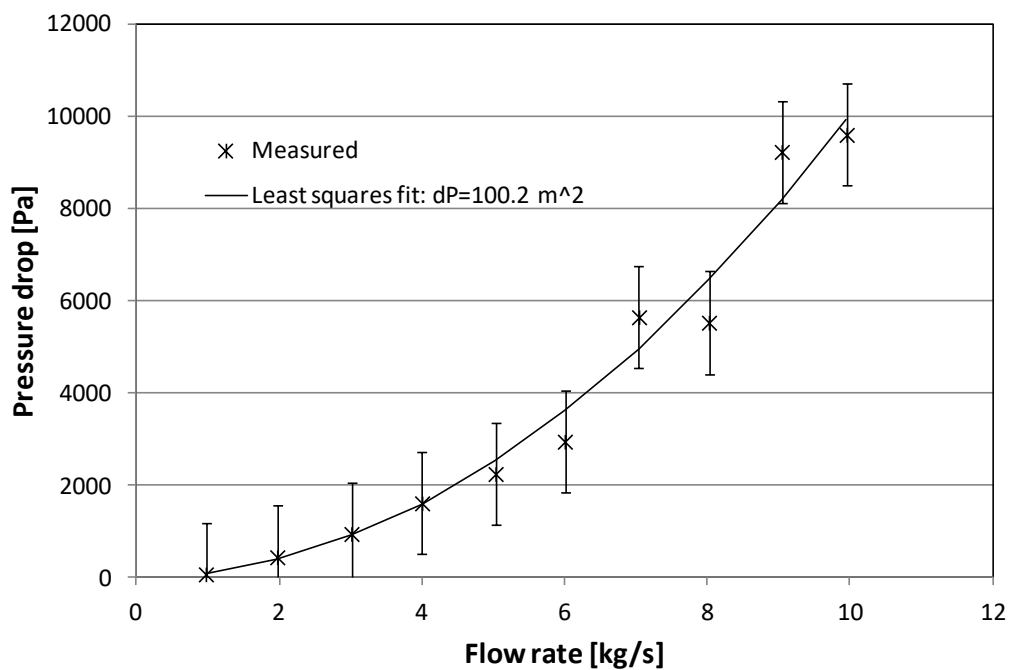


Figure G.1. Example graph with error bars



Figure G.2. Example bar graph

G.3. Statistical Symbols

Some symbols are used to convey statistical properties and those that occur most often in technical documents are considered here.

Error bars are used to show an estimate of the measurement error or uncertainty in each measured data point. Figure G.1 shows vertical error bars, indicating the uncertainty in the y-values. If the x-values also contained uncertainty, then horizontal error bars should be added.

The exact meaning of the error bar should be conveyed in an annotation, the caption or the report's text. Typically the error bars represent one standard deviation (which is only appropriate if the errors are normally distributed) or a confidence interval (for example 95%). The error bars will help the reader to determine whether differences between measured data points are significant or smaller than the uncertainty.

Box-and-whisker plots convey more complete statistical information and are appropriate where a large number of samples are reduced to a single symbol. Figure G.3 shows a plot created using Matlab's "boxplot" command. The box symbol shows the median (the bar near the middle of the box), upper quartile and lower quartile (the top and bottom of the box) of a data set. The whisker can be added to show any one of a number of additional measures of the spread of the data, for example the minimum and maximum values, or the 2nd and 98th

percentiles. The width of the box can also be used to represent the number of data points in the sample used for that box. The report's text or an annotation must convey the exact meaning of the box and whisker.

G.4. Layout

This section list a variety of guidelines for the layout of graphs:

The text of the axes' labels, axes' numbers and annotations must be about the same size as the report body's text.

The axes of a graph must be labelled. The units of the numerical values of the axis should be included in the axis label. The number of digits in the numerical values next to the axis should reflect the number of significant digits and the limited resolution of a graph. For example, if the increment in the numbers along an axis is 10 or more, then it would not make sense to give numbers such as 200.00. The units used for the labels should also reflect the effective resolution, for example rather than using increments of 1000 W, using 1 kW would be more appropriate. Note that the default settings in commonly used software often do not adhere to this guideline.

If more than one data set is shown in a graph, then the graph must have a legend describing each data set.

Data to be compared (for example different sets of experimental data, or experimental data vs analytical results) should be combined in the same graph so that the reader can make a direct comparison. The quantity of information in any one graph, however, should be limited so that the different symbols can be distinguished clearly.

The majority of technical readers intuitively expect the independent variable to be given on the x-axis, with the dependent variable on the y-axis. If this layout is not used, it should be pointed out in the text of the report.

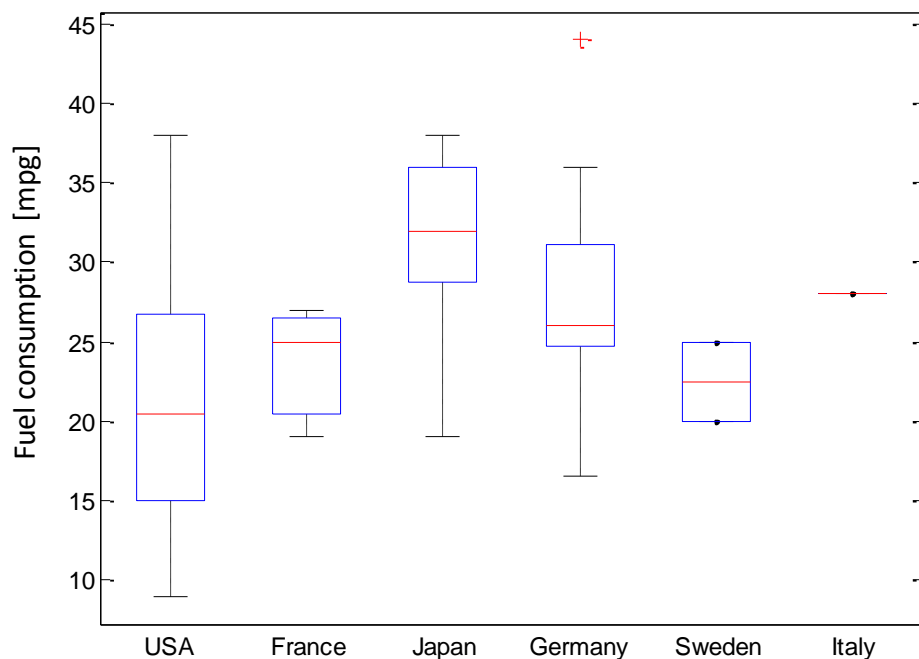


Figure G.3. Example box-and-whisker plot: car mileage, grouped by country

When only the relative values of the properties in a graph are important, an axis' maximum and minimum values can be chosen to provide the clearest portrayal of the data. However, if the absolute values are important, then it is preferable that the axis clearly shows where the zero value is.

The thickness of lines representing data in the graph should be just thick enough to be clear in a pdf and printed version of the report. The default line thicknesses in Excel, for example, are suitable for Powerpoint presentations, but much too thick for use in a report.

The caption of a graph, as for any figure, must be given below the graph. The caption added by some software, such as Excel, above the figure must be cropped or suppressed.

Colour lines generally aid in interpreting the data, but colour may only be used when black-and-white versions of the document will never be used. If there is any doubt, it is best to use both colour and shape (solid and dotted lines, different symbols, various hatchings, etc.).

Two-dimensional graphs can be read with a fair precision, but three-dimensional graphs cannot be read as accurately. If reading precise values is important, then adding grid lines to a two-dimensional graph will be useful.