How to Write a Thesis:
A Working Guide

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Contents

Abstract

This is a short guide on how to write a thesis at both the undergraduate and postgraduate levels. It is aimed at students of engineering and science. A thesis may be analysed into three S's: *structure, substance* and *style*. Structure confers logical coherence; substance, significance and depth; and style, elegance and appeal.

State your hypothesis clearly, ensuring that it is both reasonable and testable. Keep meticulous records and write up rough drafts of your work as you go along. Begin writing your thesis proper with the experimental chapters. Progress to the literature review, introduction and conclusions. Write the summary or abstract last, *after* writing the conclusions.

Write clearly and directly, with the reader's expectations always in mind. Lead the reader from the known to the unknown. Write clearly, precisely and briefly. Think, plan, write, and revise. Follow layout guidelines and check spelling and grammar. Re-read, seek criticism, and revise. Submit your best effort as your completed thesis.

1 Introduction

This is a working guide on writing a thesis. It is intended to assist final year and post-graduate students in Electrical/Electronic/IT Engineering at the Centre for Intelligent Information Processing Systems (CIIPS), and the Australian Research Centre for Medical Engineering (ARCME), at The University of Western Australia (UWA). The guide is divided into three main parts:

I Structure;

II Substance; and

III Style

The structure of a thesis is governed by logic and is invariant with respect to subject. The substance varies with subject, and its quality is determined by the technical knowledge and mastery of essentials exhibited by the student. Style has two components: language and layout. The former deals with the usage of English as a medium of sound technical communication; the latter with the physical presentation of the thesis on paper, according to the requirements laid out by UWA. All three components—structure, substance and style—influence one another. A good thesis will not be found wanting in any of these three[1].

1.1 What is a thesis and why write one?

thesis/ˈθiːsɪs/ *n* **1** a proposition to be maintained or proved. **2** a dissertation esp. by a candidate for a degree. [Middle English via Late Latin from Greek = putting, placing, a proposition, etc.] [1]

hypothesis/hʌɪˈpɒθɪːsɪs/**1** a proposition made as a basis for reasoning without the assumption of its truth. **2** a supposition made as a starting point for further investigation from known facts. [Late Latin from Greek *hypothesis* 'foundation'; Greek *hypo* 'under'] [1]

One might infer from the etymology above that a thesis is an (obligatory) offering *placed* at the desk of the examiner by a candidate who wishes to get a degree. This is the most common, and often only, reason why a thesis is written. But there *are* other reasons for writing a thesis.

A thesis is a written record of the work that has been undertaken by a candidate. It constitutes objective *evidence* of the author's *knowledge* and *capabilities* in the field of interest and is therefore a fair means to *gauge* them. Although thesis writing may be viewed as an unpleasant obligation on the road to a degree, the *discipline* it induces may have lifelong benefits.

[1]This guide does not cover the earlier phases, such as selecting a supervisor and research topic, doing a literature search etc., nor does it give advice on how to do research, except as it pertains to writing a thesis.

Most of all, a thesis is an attempt to *communicate*. Science begins with curiosity, follows on with experiment and analysis, and leads to findings which are then shared with the larger community of scientists and perhaps even the public. The thesis is therefore not merely a record of technical work, but is also an attempt to communicate it to a larger audience.

1.2 Differences between the undergraduate and postgraduate theses

The differences between the undergraduate and postgraduate theses is one of *degree*[2] rather than *kind*. They share a common structure and need for logical rigour. It is only in the substance and the emphasis placed on it that the differences arise. Specifically, UWA requires that:

> A PhD thesis shall be a substantial and original contribution to scholarship, for example, through the discovery of knowledge, the formulation of theories or the innovative re-interpretation of known data and established ideas [2].

An undergraduate thesis is, at present, graded on the *quality of research*, the *significance of the contributions* and the *style of presentation*.

Thus, the undergraduate thesis is judged on a similar basis to the postgraduate one. Indeed, the three most commonly cited qualities that earn an undergraduate thesis the first class grade are *originality*, *independence*, and *mastery* [3].

Candidates writing a higher degree thesis—and the PhD thesis in particular—are required to present their research in the context of existing knowledge. This means a *thorough* and *critical review* of the literature, not necessarily limited to the narrow topic of research, but covering the general area. The PhD candidate should also show clearly what *original contributions* she or he has made [2]. Although neither of these requirements applies strictly to undergraduate work, the candidate should demonstrate familiarity with previous relevant work in his or her thesis.

In short, a thesis—whether undergraduate or postgraduate—is evidence of the candidate's capacity to carry out independent research under the guidance of a supervisor, and to analyse and communicate the significant results of that work. The candidate for higher degrees must demonstrate, in addition, mastery of the literature and indicate clearly which is his or her original work, and why it is significant[3].

[2] Pun unintended!

[3] Contrary to custom elsewhere in the world, the candidate for a master's or doctoral degree at UWA is generally not required to make an oral presentation and defence of her or his work. By contrast, the final-year Electrical/Electronic/IT Engineering student is required to make an oral presentation that contributes a small percentage to the total marks for the thesis.

2 Structure

2.1 Thesis structure at UWA

The UWA PhD regulations [4] give the following format for the doctoral thesis:

1. Title page: gives the title of the thesis in full, the candidate's names and degrees, a statement of presentation in the form 'This thesis is presented for the degree of Doctor of Philosophy of the University of Western Australia', the department and year of submission.
2. Summary or Abstract—of approximately 300 words. (It should not exceed 700 words.) The Abstract or summary should summarize the appropriate headings, aims, scope and conclusion of the thesis.
3. Table of Contents
4. Acknowledgements
5. Main Text
6. Bibliography or References
7. Appendices

The format of the undergraduate thesis is similar, except that the title page is followed by a letter from the candidate addressed to the Executive Dean of the Faculty of Engineering and Mathematical Sciences saying 'This thesis is submitted in partial fulfilment of the requirements for the degree of Bachelor of Engineering (with Honours)' and certifying that it represents the candidate's own work.

The thesis proper consists of the Main Text, numbered 5 above. If we zoomed in on the Main Text, we should see something like this [5, p 110]:

(a) Chapter 1: Introduction

(b) Chapter 2: Review of the Literature

(c) Chapter 3: Materials and Methods

(d) Chapters 4 to n: Experimental Chapters

(e) Chapter $(n+1)$: General Discussion or Conclusions

If we now zoomed in on any Experimental Chapter (labelled (d) above), we should expect to see [5]:

i. A brief introduction

ii. Experimental procedure (methods and materials)

iii. Results

iv. Discussion

This structure reflects the time-honoured format of science experiments:

I. Aim

II. Materials and Methods

III. Observations

IV. Results

V. Discussion

VI. Conclusions

We have just dissected the structure of a (scientific or engineering) thesis but have we obtained any insights in return?

2.2 Rationale for structure

The rationale for the structure in section 2.1 is simply that *a thesis must tell a story clearly and convincingly.* The components of the structure impart logical continuity to the thesis in much the same way that links in a chain confer on it integrity and strength. There is a flow in the logic, as shown in Table 1, which is adapted from [6, p 131]:

Introduction/Aim	*What did you do and why?*
Materials and Methods	*How did you do it?*
Observations/Results	*What did you find?*
Discussion	*What do your results mean to you and why?*
Conclusions	*What new knowledge have you extracted from your experiment?*

Table 1: This table shows the relationship between the structure of an experimental chapter in a thesis, and its underlying logic.

Any flaw in the reasoning or gap in the logic will be easily spotted if this structure is strictly followed. *Thus, the structure of the thesis is designed to enforce logical and scientific rigour and make it easy to read.* Follow the structure and you can be sure that you are telling your story in the right order. But what exactly *is* your story?

2.3 The hypothesis underpins the thesis

The *hypothesis* is all important. *It is the foundation of your thesis.* It gives coherence and purpose to your thesis. Go back to section 1.1 to review the meaning and etymology of this word. If it is hard to grasp what hypothesis means, these explanations might help:

- The hypothesis defines the aim or objective of an experiment, that if some likely but unproven proposition were indeed true, we would expect to make certain observations or measurements.

- A hypothesis is an imaginative preconception of *what might be true* in the form of a declaration with verifiable deductive consequences [7, p 18].
- Hypotheses are the larval forms of theories [7, p 20].
- 'In every useful experiment, there must be some point in view, some anticipation of a principle to be established or rejected'; *such anticipations are hypotheses* [7, John Gregory quoted by Medawar, p22].

Indeed, the great French physiologist, Claude Bernard, has written:

> A hypothesis is ... the obligatory starting point of all experimental reasoning. Without it, no investigation would be possible, and one would learn nothing: one could only pile up barren observations. To experiment without preconceived ideas is to wander aimlessly. [7, p 30]

Your *hypothesis* must *fit the known facts*[4] and *be testable*. To comply with the first, you must have read the literature. To comply with the second, you must do the experiment. This is why the hypothesis is central to scientific investigation [5].

If you find time, read an account of the famous Michelson-Morley experiment [8] to understand that if hypothesis and experiment are in conflict, it is experiment that prevails and hypothesis that falls. If an experiment shows that a hypothesis is incorrect, then that hypothesis must be erroneous, no matter how attractive. Moreover, failure of a hypothesis may lead to a re-examination of assumptions, refutation of shaky theories, and ultimately to new knowledge, as happened in this case.

2.4 Does an engineering thesis need a hypothesis?

Hypotheses may be relevant to science theses, but are they relevant to engineering theses? Because engineers *invent* rather than *discover*, does an engineering thesis need a hypothesis?

Yes, all the more so, because invention is a more tightly *directed* activity than discovery; and the two are not mutually exclusive anyway! I prefer the word hypothesis: *that which underlies a thesis*; you may be more familiar or comfortable with *aims* or *objectives*. The hypothesis is the *electromotive force* or *emf* for your thesis.

Suppose your project involves using Artificial Neural Networks (ANNs), in conjunction with appropriate hardware, to sort good apples from bad. The hypothesis for this project may be, 'It is possible to sort good apples from bad using ANNs and suitable hardware'. Note that implicit in your hypothesis is a definition of acceptable levels of accuracy (how do you *quantify* the words 'possible', 'good', and 'bad'?).

Suppose that on completing your project, you discovered that the system you had devised works well with green apples, but not with red ones. You would have *discovered new knowledge* and would be able to suggest a *revised hypothesis* as the starting point

[4] But you should not be afraid to explore the unknown. If the "known fact" that "atoms are indivisible" had not been challenged, we would not have known of electrons, let alone quarks.

for further investigation. Your own project would have demonstrated[5] the correctness of a hypothesis like 'It is possible to sort good green apples from bad green apples, with an accuracy of better than 90%, using ANNs and suitable hardware'.

Never forget that underlying every thesis, there must be a hypothesis. It is what your story is all about. If you keep your hypothesis in view, you will never stray into irrelevance when writing your thesis, which is what we look at next.

3 Substance

3.1 Begin at the beginning[6]: keep records

The content of your thesis is being continuously gathered throughout the period of your project/research. Remember this and keep clear, well-annotated records in your "CIIPS Research Record Book". You can afford to be wordy and repetitive here, because you do not want to be lost when you refer to it later on. Because it is a running record of experiment and observation, its only requirement is fidelity; not subsequent correctness.

Michael Faraday was an experimental scientist par excellence. His diary of his researches can serve very well as a model of how your own research record book should be like. For example, in one volume of his diaries [10], he has recorded the following:

- freehand drawings of experimental setups [pp 248–9]. You should do the same; your diagrams in your record book need not be works of art: save that for the thesis!
- his accurate description of what he *believed* he was *perceiving*: "It still *smelt strongly of Electricity*" [p 200]. The italics are his. Today we may hide a smirk if anyone talks about smelling electricity; but remember that these are the observations of a scientific pioneer. Do not be afraid to record your *perceptions accurately.*
- his own questions to himself: "Can induction through air take place in curves or round a corner?" [p 420]. Such questions serve to clarify your own thoughts and to steer further work.

In summary, your record book is where you *record your thoughts, perceptions and measurements, using words, numbers and pictures, as and when they are still fresh in your mind.*

Plan your experiments so that one experiment has only one hypothesis. Many experiments may together shed light on a larger, unifying hypothesis.

Assuming that your experimental work is going well, the spectre of writing it up, so that it looks like a thesis, still looms ahead. How do you do that?

In the following sections, we take a look at some guidelines on how to write well. This is followed by advice from some experienced UWA professors on how to write a good

[5] Philosophers of science contend [7] that a hypothesis cannot be proved conclusively, but only falsified. We will steer clear of this controversy here.

[6] "Begin at the beginning," the King said gravely, "and go on till you come to the end: then stop." *Alice's Adventures in Wonderland* by Lewis Carroll [9, p 158]

thesis. The material that follows is the core of this working guide: so pay attention to it and try to understand it thoroughly.

3.2 Write with the reader in mind

All communication involves two parties: the sender of the message and the receiver; in written communication, they are the writer and the reader. If you *write with the reader in mind* you are more likely to communicate successfully. To fix this concept in your mind, I will introduce two analogies from electrical engineering with which you *must* be familiar:

1. the maximum power transfer theorem: [11, p 432] The transfer of power from a source to a load is maximum if the load impedance is the complex conjugate of the source impedance (see Figure 1). The matching of *source* and *load* impedances for *maximum power* transfer to occur is analogous to matching the *writer's technique* to the *reader's expectations* for *maximum communication* to occur.

2. there are *no reflections* on an ideal, lossless transmission line if it is terminated with a load that is equal to the *characteristic impedance* of the transmission line [12, p 355]. The *reflections* at the end of a transmission line are like the reader's *confusion* at what the writer intended to convey; such confusion is minimized again by *matching what the reader expects with what the writer provides.*

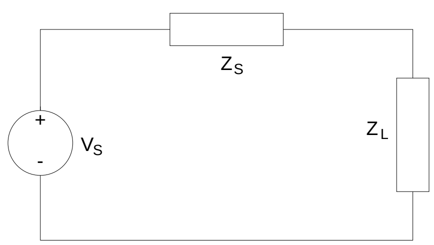

FIGURE 1: Maximum power is transferred from the source V_S if the load impedance Z_L is the complex conjugate of the source impedance Z_S, i.e., if $Z_L = Z_S^*$ [11, p 432].

Gopen and Swan [13] have written an excellent article introducing scientific method into scientific writing. They claim that readers have certain implicit expectations about *what to encounter* and *when*, each time they read a sentence. If the writer matches these expectations, communication takes place easily; otherwise confusion or misinterpretation results. They exhort the writer *to write so as to match the reader's expectations.* The reader should not waste the effort that would go into *understanding the substance* of the writing, in trying to *guess* what the writer *intended to mean.* Although they warn that "there can be no fixed algorithm for good writing", they give seven sound generic guidelines that are worth re-stating here [13]:

1. Follow a grammatical subject with its verb, as soon as possible.

2. Place in the position of importance (stress position) the "new information" you want the reader to emphasize in his or her mind.

3. Place the person or thing whose story is being told at the beginning of a sentence in the topic position.

4. Place appropriate "old information" (material discussed earlier) in the topic position to provide *linkage* with what has gone before and *context* for what is to come later.

5. Make clear the action of every clause or sentence in its verb.

6. Provide context for your reader before asking him or her to consider anything new.

7. Match the emphasis conveyed by the *substance* with the emphasis anticipated by the reader from the *structure*.

In summary, match the reader's expectations by constructing sentences skilfully. *Lead the reader from the known to the unknown.* Write with the reader in mind: this is usually the examiner, but do not forget the poor student who gets to continue your project the next year. If your thesis is not clear enough, he/she may be condemned to repeat your work before making further progress, losing valuable time in the process.

3.3 Think-Plan-Write-Revise

Think. Plan. Write. Revise. This is the cycle advocated by Barrass [6] in his short but very useful book on scientific writing. Messy thinking leads to messy writing: cluttered, obscure and uninviting. Think and plan before you write and revise.

Writing is not a linear process but a cyclic one. What appears first may be written last, with the benefit of hindsight and a unified perspective. But, where does one start; how does one revise, and how many times? As an entrée, let us listen to those with experience.

3.4 Attikiouzel's aphorisms [14]

1. *Start writing early.* Do not delay writing until you have finished your project/research. Write complete and concise "Technical Reports" *as and when* you finish *each nugget* of work. This way, you will remember everything you did and document it accurately, when the work is still fresh in your mind. This is especially so if your work involves programming.

2. *Spot errors early.* A well-written "Technical Report" will force you to think about what you have done, *before* you move on to something else. If anything is amiss, you will detect it at once and can easily correct it, rather than have to re-visit the work later, when you may be pressured for time and have lost touch with it.

3. *Write your thesis from the inside out.* Begin with the chapters on your own experimental work. You will develop confidence in writing them because you know your own work better than anyone else. Once you have overcome the initial inertia, move on to the other chapters.

4. *End with a bang, not a whimper.* First things first, and save the best for last. First and last impressions persist. Arrange your chapters so that your first and last experimental chapters are sound and solid.

5. *Write the Introduction* after *writing the Conclusions.* The examiner will read the Introduction first, and then the Conclusions, to see if the promises made in the former are indeed fulfilled in the latter. Ensure that your Introduction and Conclusions match 100%.

6. *"No man is an Island"*[7]. The critical review of the literature places your work in context. Usually, one third of the PhD thesis is about others' work; two thirds, what you have done yourself. After a thorough and critical literature review, the PhD candidate must be able to identify the major researchers in the field and make a sound proposal for doctoral research.

7. *Estimate the time to write your thesis and then multiply it by three to get the correct estimate.* Writing at one stretch is very demanding and it is all too easy to underestimate the time required for it; inflating your first estimate by a factor of three is more realistic.

3.5 Lindsay's laws [5, 15]

1. Research is finished only after it is written up. What you write must *communicate* and *persuade.*

2. The hallmarks of scientific writing are *precision, clarity* and *brevity, in that order.*

3. Try to write as if you were speaking to someone: "see a face". This way you get to say it directly and clearly.

4. Write (your chapters) in *four drafts*:

   (a) first: putting the facts together
   (b) second: checking for coherence and fluency of ideas
   (c) third: readability
   (d) fourth: editing

[7]No man is an Island, entire of itself; every man is a piece of the Continent, a part of the main; if a clod be washed away by the sea, Europe is the less, as well as if a promontory were, as well as if a manor of thy friends or of thine own were; any man's death diminishes me, because I am involved in Mankind; And therefore never send to know for whom the bell tolls; It tolls for thee.—John Donne (1571–1631), *Meditation XVII*

Full details are given in Lindsay's book [5, chapters 1 to 4].

5. The Introduction should embody the (unified) hypothesis. The reader finds in a clearly expressed hypothesis the skeleton of the thesis on which hangs all of the skin and meat that will be presented later.

6. The scope and emphasis of the Literature Review must be directly relevant to the subject of the thesis.

7. Include a common chapter that presents in one place all the experimental details common to all your experimental chapters. This avoids boring repetition and clears the way for a more fluent presentation of experimental results in different chapters without the intervening distraction of tedious methodology.

8. Experiments and results must be set out in careful detail in individual chapters. See i. to iv. on page 5 for the structure of each experimental chapter. Where several related experiments are grouped into a single chapter, it is preferable to present this sequence individually for each experiment but to conclude with *one* Discussion. This will meld the experiments together and unify the chapter.

9. The General Discussion or Conclusions integrate the whole thesis and present its main points at one place. This should be done in the context of the unifying hypothesis of the thesis. The Introduction and this chapter along with the Summary or Abstract are the most important parts of the thesis.

3.6 Hartmann's hints [16]

Listed below are hints on writing the *PhD thesis*, gleaned from a seminar at UWA [16], with points made largely by the first speaker during split group discussion, and subsequently by all three speakers at a panel discussion. Undergraduate students may optionally skip this section.

1. *Title.* The title should be succinct, focussed and objective, giving, if possible, the scope of the thesis.

2. *Abstract or Summary.* Examiners will look here to find out whether it is new knowledge; and if so what.

3. *Introduction.* Remember that the introductory pages are important because they create the first, and perhaps lasting, impression on the examiner. Use flow diagrams, headings, sub-headings etc., to create and sustain interest.

4. *Literature Review.* This should be a *critical synthesis* of the state of the knowledge. Especially important are the areas needing further investigation: what has not been done, as well as what has been done, but for which there is a conflict in the literature. The examiner finds out *how the candidate thinks* from reading this section.

5. *Hypothesis Testing.* The hypothesis must be framed carefully and experiments designed thoughtfully to test it.

6. *Materials and Methods.* Ensure proper quality control and statistical planning and analysis. Retain enough details to allow repetition of experiments for up to seven (7) years, as legally required.

7. *General Discussion or Conclusions.* You may afford to be speculative here.

8. Examiners ask the following questions when reading a thesis:
   - Has the student read all the references?
   - What questions does this thesis raise?
   - What richness does it contain that can spawn other work?
   - What is the quality of flow of ideas?

9. Keep in mind that examiners read a thesis in instalments and display a *natural benevolence,* i.e., they do not set out to read a thesis with the aim of failing the student.

10. Read the *whole* thesis to pick up repetition.

11. Read your thesis for *ideas* and read it again for *editing* (see point 4 in section 3.5).

3.7 Cobbling together your first draft

According to Newton's first law, *starting something new* is difficult because inertia must be overcome[8]. Writing a thesis from scratch is no exception. This is why I suggested that you start writing your thesis *before* you know you are writing it: by keeping complete notes in your "CIIPS Research Record Book" and by writing "Technical Reports" as and when you complete each module of work.

Use whatever writing techniques you are familiar and comfortable with. If, for example, you like to jot down "bullet points" before you formally commit your thoughts to writing, do so by all means. If you have used "mind-maps" [17] in your study technique, you may wish to apply them to write your thesis too. Marshall whatever resource or technique that has worked for you, and use it to help you write your thesis.

You are now familiar with the structure of the entire thesis and also with that of each experimental chapter (see section 2.1). You have also benefitted from the counsel of several experienced UWA professors. Let us now tackle the nitty-gritty of actually writing the thesis, more or less in the order you should go about it.

[8] I have taken pedagogic licence here by extrapolating Newton's laws from the physical to the mental.

3.8 The Experimental Chapters

Each of these should preferably be self-contained and clearly focused. Think of the story you want to tell. *Choose and present only those results that are relevant to your hypothesis.* A morass of experimental results unilluminated by a hypothesis and unembellished by a discussion is insulting and confusing to your reader.

The sections in your chapter should follow the experimental schema set out in Figure 2. State your hypothesis clearly. Indicate all assumptions. Include enough information about materials and methods to enable another suitably qualified person to repeat your experiments. Relegate tedious but necessary details to an Appendix, so that there are no breaks in the flow of ideas in your presentation.

If you chose some "magic numbers" for your programs, or some specific conditions for your experiment that may not be readily apparent to your reader, *explain* the reasons for your choice here.

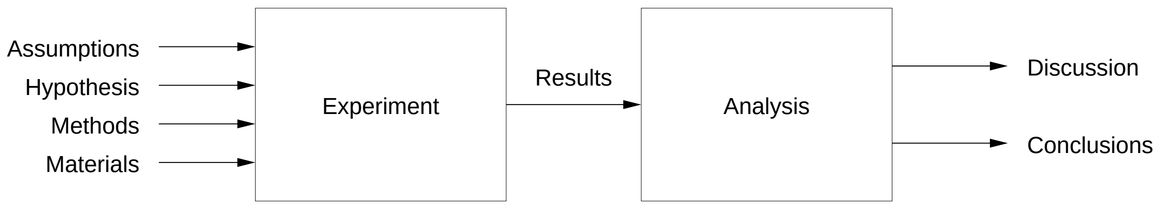

FIGURE 2: This diagram illustrates the relationship between the different stages in the experimental process. Do not intersperse your Results with Materials and/or Methods. Resist the temptation to pepper your Results section with a Discussion.

Do not mix Materials and Methods with Results [18]; they are quite distinct in Figure 2. It is customary to describe your Methods before the Materials. For example, you would describe your algorithm before giving details about the dataset on which you developed and tested it. Use informative headings. If you are using a method that has already been documented in the literature, do not describe it in full; describe it briefly or not at all, and give a reference citation [15].

When to present your results in a table and when to show them in a graph is discussed in section 5.3.

If your results convey no sense of the new or the unexpected, you must ask yourself whether they are the right results to present, and also whether your hypothesis was well framed in the first place. If your results are insipid, if they say nothing new, shed no light on what was unknown and generally convey no sense of excitement or new knowledge, you should sit down and think carefully about everything you have done. A discussion with your supervisor may also be in order.

Do not present results chronologically; present them logically.

Adopt a standard nomenclature for all your chapters and introduce this in one place, preferably in a chapter preceding your experimental work, and entitled "Common Materials and Methods", or "Experimental Framework and Notation", or something similar.

Do not change your symbols and their meanings as you go along: this will irritate your reader no end.

Check all facts and results at least once, twice if possible.

Use SI units and the preferred abbreviations. It is unprofessional to write 75 mhz when you mean 75 MHz. Leave a blank space between the number and the SI unit and do not put a full stop after the abbreviation, unless it is at the end of the sentence.

Try to present your Results separately from your Discussion. There is a temptation to commingle fact and opinion, but resist it. Your work will be easier to understand if your results (measurements, observations, perceptions) are separated from your discussion (inferences, opinions, even conjectures).

The Discussion section of your experimental chapter is where you add value to your work. This is where you comment on your results. Why are they what they are? What meaning can you wrest from them? Are they in accord with accepted theory? What do they mean with respect to your hypothesis? Do your results uphold your assumptions? How do you treat unexpected or inconsistent results? Can you account for them? Do your results suggest that you need to revise your experiments or repeat them? Do they indicate a revised hypothesis? What are the limitations in your methodology? How do your results fit in with the work of others in the field? What additional work can you suggest?

An A^+ student distinguishes himself or herself by the quality, depth, knowledge and subject mastery that is apparent from the discussion. Even if the hypothesis fell as a result of the experiment, an excellent discussion of results alone can earn you an A^+.

Throughout your thesis, and especially in your experimental chapters, there should be *no gaps in the flow of logic.* Keep the links of a chain in mind. Each link is connected to two other links: one before and one after. Absence of any one link is a weakness. Absence of both means there is no chain!

To sum up, your overall purpose is to tell a good story: interesting, coherent, and plausible. Use your results to serve this purpose, keeping the hypothesis in mind.

3.9 The Literature Review

The literature review is the backdrop on which you present your work. It must be selective, but substantial enough for the merits of your work to be judged in relation to what is known. It is especially critical for a PhD thesis where the claim of originality should be defended with a thorough and critical review of the literature, especially in your specific area of research. You should capture the essence of current knowledge and comment critically on where the interesting questions and inconsistencies lie. The literature review is vital to justify your hypothesis, which must be consistent with what is known. If you present your literature review objectively but selectively, so that it does not stick out as an extraneous chapter, but merges into the larger story of your thesis, you would have done well.

3.10 The Introduction and Conclusions

The Introduction is where you "soft launch" your reader on the work described in your thesis. *Lead the reader from the known to the unknown.* State the hypothesis clearly. Give a preview of your thesis, globally and chapter by chapter. Your Introduction has done its work if you have captured the reader's curiosity and interest in this first chapter.

The Conclusions record the power of your scientific thinking. You have to unite all that has gone before with a "thread of unified perspective". This is where you say why you think your story is a good one and present evidence from your work to support your claim. The fate of your hypothesis is revealed here: did it stand, fall, or require modification? You may briefly compare your work with that of others, present whatever new knowledge has been gained from your work, and suggest what may be done to further new knowledge. The Conclusions should give a sense of fulfilment and finality to your thesis, and give the reader some satisfaction that the time spent on reading it has not been in vain.

Write the Introduction *after* you have written the Conclusions and make sure the two match (see section 3.4).

3.11 Linking your chapters

While you are writing your thesis, you might suddenly remember that an idea in Chapter 3 needs to be linked to an idea in Chapter 5, etc. This is a healthy sign because it means that you are integrating your work and seeing your thesis as one whole in your mind. These forward and backward linkages give continuity to your thesis. Keep a stack of pages, one for each chapter, where you can write down these aides-mémoire, *as and when they occur to you.* As you finish writing each chapter, check the "linklist" for that chapter and ensure that you have not forgotten anything.

3.12 The Summary or Abstract

The Summary or Abstract is perhaps the most difficult part to write. Do not make the mistake of trying to write it first: you will waste time and get discouraged. The Abstract should be written last. You will then have a feel for the story being told by your thesis: a bird's eye view so to speak, that was lacking when you had your nose to the grindstone, writing the Experimental Chapters or the Literature Review. *This unified perspective is vital to writing the Summary.*

I have found the following exercise very helpful in trying to focus the mind on what the point of a thesis (or paper or article) is. Try condensing your thesis in:

- one word;
- one line;
- one sentence;
- one paragraph;

- one page; and
- one chapter.

This method is somewhat like asking a dying man for a message: he will tell you only the most important thing(s). You begin at the most "compressed" level of describing your thesis and successively relax the constraint on the number of words to achieve increasing levels of detail. Somewhere along the way, you should have written your one- to two-page abstract, summarising your thesis adequately. This is a disciplined way to distill what is important from what you have written[9]. If you have not gone through this process yourself, it is unfair (and risky) to expect the examiner to do it for you.

3.13 Writing other parts of your thesis

The Title should be neither too long nor too short. It should be focused and interesting. It should include the keywords you might use to describe your work in a scientific paper or thesis-abstracting system. Try to use some verbs rather than a long list of nouns.

The Acknowledgements should include sources of financial support and all those whose help you have sought and got, and all those whose work you have directly built upon.

The Bibliography should only contain references you have actually read. To quote an unread paper is misleading and dangerous. In engineering theses, references are usually cited by number, in order of citation.

Sometimes, it may be necessary to digress from your main story to explain something, especially for completeness. For example, it may be some experimental details, an analytical method, a program listing, etc., that is not central to your story, but whose exclusion would make your thesis incomplete. Include such material in an Appendix. Moreover, do not parrot textbook material in an Appendix just to give your thesis length or to impress your examiners. In all likelihood, they would ignore such material and could take marks off for gratuitous length.

3.14 Polishing up your thesis

As and when each chapter is written, read it for understanding, paying attention to the flow of logic and sense of continuity. Then read it again, paying attention this time to how comprehensible it is. Finally, read it once more paying attention to spelling, grammar, typography, placement of illustrations, etc. In these three stages, you are evaluating the chapter for its structure, substance and style (see also section 4.1).

At each reading, revise your thesis as you feel appropriate.

When all the chapters are in place, read the thesis again, paying attention this time to *overall* understanding, coherence, comprehensibility and presentation.

Get your supervisor, and anyone else whom you can approach, to read and criticize the early drafts of your thesis. The more you polish up your thesis, the better your chances

[9] The Abstract is *not* a summary of the *entire* contents of your thesis, but only of its *salient* points, including the *major findings and conclusions.*

of getting high marks for it. A well-written thesis is like a piece of highly polished fine furniture: its elegance bespeaks its worth.

3.15 The time element

It is very easy to underestimate the time needed to plan, write and revise your thesis. As a general guideline, allow one to three months for writing up an undergraduate thesis and at least six months for a PhD thesis. As another rule of thumb, triple your initial estimate to arrive at a more realistic time frame.

The task of writing up will not loom large at the end of your project if you have written your thesis in instalments as suggested in this guide.

Do not procrastinate, however much you dislike writing. Remember that writing up is also an integral part of your project or research work. Schroeder gives an interesting analysis, using a self-similar model, of how "...the longer one works on such a project without actually concluding it, the more remote the expected completion date becomes" [19, p 157].

This paragraph is addressed especially to PhD students. The period when you are writing up is the period when you are most vulnerable: the excitement of the research is now behind you, your scholarship would be running out or might already have, financial pressures will intensify, and there may be an obligation to work part-time and write up part-time. There may also be attractive job offers vying for your attention. Do not lose motivation during this difficult period. Loss of motivation is one of the principal ways in which you can deprive yourself of your PhD [20]. Write up your thesis and get on with the rest of your life.

3.16 Do's and Don'ts in Science and Engineering

- Do keep records as you go along and date them.
- Do systematic work.
- Don't claim precision where it is not justified.
- Don't present a conjecture as a fact.
- Don't plagiarize.
- Don't falsify records or cook up data.

4 Style: Language

4.1 The craft of writing good English

Writing good English is a craft. It has to be learned by careful reading and even more careful writing. You must develop your own *style:* no one can teach or bequeath it to you. It helps to read books devoted to the subject [21–27], but it helps even more to read exemplars of good writing. I particularly like and recommend the books of the chemist Peter Atkins [28, 29] and the biophysicist Harold Morowitz [30] which popularize science. These authors have demonstrated how it is possible to present science simply, correctly and engagingly.

As you progress in developing your own style, you will develop an internal feedback mechanism that will tell you just when the rhythm, length and structure of a sentence is right, and when it needs revising.

Read what you have written, slowly and carefully. *If you find yourself backtracking for any reason, revise what you have written.* This may be because of bad sentence structure, poor punctuation, excessive sentence length, poorly expressed ideas, or an unfortunate choice of words. Whatever the cause, take the trouble to revise it: if you yourself stumble on your own writing, your reader is bound to stumble too. The least courtesy you can do to your reader is to revise your writing.

Verbs are words of action. They infuse life and meaning to your writing. A long catalogue of nouns is lifeless; throw in a verb to add some sparkle!

Style and substance are intertwined. Say *clearly* why the busy reader should give *you* her time and attention, when so many others are clamouring for it, and say this *early.* Think of your writing as a tense wire connecting your reader to you. If everything you say is old hat to the reader, the wire is slack and you have lost your reader to boredom or even sleep. If everything you say is new and not linked to something the reader already knows, the wire is too taut and will break at some point. You will again lose your reader, but this time to incomprehension. Monotony leads to boredom; unpredictability to confusion. You have a duty to keep the reader challenged but not frustrated, engaged but not confused, comfortable but not bored.

The sections that follow are devoted to clarifying what good scientific writing is and should be.

4.2 Ambiguity and Clarity

Ambiguity has its place. The novel *Finnegans Wake* by the great Irish author James Joyce [31], was first published in 1939. Starting with its title, the novel was open to several interpretations. Indeed, Joyce had claimed that this book "...would keep the professors busy for centuries" [32] and that is indeed one of its merits. It has proven to be such a rich source of layered meanings that there is at least one interpretive book with a *scientific* flavour, that has a chapter entitled "*Finnegans Wake*: The Complexity of Artificial Life" [33].

Scientific writing, however, must be unambiguous and the engineering thesis is no exception. It must communicate clearly,[10] precisely and briefly. Say what was done; how it was done; why it was done etc., following the guidelines of Gopen and Swan in section 3.2, to minimize the possibility of ambiguity and misinterpretation.

[10]Those for whom English is a second language sometimes mistakenly think that good English should be convoluted. This is not true. Good English is clear and easy to read and understand. The cardinal rule is to *keep it simple.*

4.3 Precision

Precision distinguishes science as a field of intellectual endeavour. It is vital in quantitative work. Precision allows your work to be repeated by others for verification and extension. Vagueness hides in expressions like "quite small", "a considerable length" etc. Avoid them. They will besmirch your writing and your work.

Precision, accuracy and experimental error are an inseparable triad. You should know how they differ and why they are related. If not, read a good text on the subject, for example [34, 35]. Precision is related to *resolution* of measurements; accuracy, to *fidelity* with truth; and error with *departure* from truth. All measurements embody errors, limited by technique, instrumentation and other factors.

Do not record a measured voltage, for example, to five decimal places simply because a digital multimeter displays it to that many decimal places. Generally, if a measured voltage is quoted as 5 V, it means the value could be in error by *half the least significant digit*, i.e., the true value lies within the interval 5 ± 0.5 V. Two other popular conventions used in stating experimental results are: $\langle v \rangle \pm \sigma_v$ and $\langle v \rangle \pm 3\sigma_v$ where $\langle v \rangle$ is the mean of a series of measurements of voltage, v, and σ_v is the standard deviation. State the convention you have used in your thesis and stick to it throughout.

4.4 Brevity

Each of us is faced with more information than we can cope, let alone digest. The reader of your thesis is no exception. As a courtesy to your reader, be brief. Repetition frustrates the able reader. However, brevity must not be at the expense of clarity or precision. *Avoid saying the same thing twice except by choice.* Eschew expressions like "in order to", "as a result of", etc. When revising your thesis, try deleting phrases and expressions that are "fillers"; in most cases, what remains would be clearer and read better.

The use of acronyms is convenient and often unavoidable in specialist writing. Some acronyms like "laser",[11] have become entrenched in the common vocabulary. However, acronyms hold other, darker attractions, especially for students: they may be used to advertise the writer's erudition[12] or to separate the cognoscenti from the "ignoscenti". Such use of acronyms is best avoided, or it could lead to their proliferation, and the disease, *acronymosis*,[13] which destroys readability and sacrifices clarity for brevity.

4.5 Examples of what to avoid

Lindsay [5] gives ten categories of cumbersome expressions that should be avoided in writing a scientific paper or thesis. These are summarized below (using his examples, mostly):

[11] *L*ight *A*mplification by *S*timulated *E*mission of *R*adiation.

[12] SMTP sounds so much more learned (and complicated) than "*S*imple *M*ail *T*ransfer *P*rotocol" when used in the context of e-mail.

[13] I am indebted to Prof. David Lindsay for introducing me to this priceless word.

1. *Clusters of nouns.* When clustered together, all nouns except the last function as adjectives. Avoid expressions like "chemical healing suppression" and say instead, "suppression of healing *by* chemicals", or "suppression *of* chemical healing", or whatever else you intended to mean. Use prepositions to make your meaning clear.

2. *Adjectival clauses.* Instead of "an innovation based return on investment culture", say "a culture *of* innovation based on return-on-investment" or whatever you actually meant to say. Again, use prepositions to make your meaning clear, even if this construction is longer.

3. *Subordinate clauses at the beginning.* This style puts the unimportant bits first and the important ones later. It may be good electronics to do so (LSB[14] first), but it is bad English. Avoid beginning sentences with constructions like "Despite the fact that ...", "Notwithstanding the fact that ...", etc. Compare these two versions:

   > Thus, although there were too few plots[15] to show all of the interactions which we sought [subordinate clause, apologetic], under the conditions of the experiment [subordinate phrase, conditional], copper and zinc acted additively [5, p 47].
   >
   > Thus, copper and zinc acted additively under the conditions of our experiment, although there were ... [5, p 47]

   The second sentence certainly reads better. It is also a good example of putting the important information in the *topic position*, which is at the beginning (see section 3.2).

4. *Nouns instead of the verbs from which they are derived.* Avoid writing "Recording of pulse rates was made"; instead write, "Pulse rates were recorded". We have improved the original sentence in three ways by doing this. We have:

   (a) replaced the original *dummy* verb "made" with the *genuine* verb "recorded";

   (b) shortened the sentence; and

   (c) sharpened the impact.

5. *Use of filler verbs.* Do not write "We conducted a study of group III-V compounds"; instead say, "We studied group III-V compounds". The second sentence has five words; the first, eight. Again, a dummy verb has been replaced with a genuine verb and the sentence has been shortened and strengthened. Examples of dummy-verb constructions to be avoided are "to be present", "to occur", "to perform", "to obtain", etc.

6. *Use of passive voice rather than active voice.* Passive voice is appropriate when the doer of an action is unknown or is irrelevant. Otherwise, passive voice lengthens

[14]Least Significant Bit

[15]Plot of ground, presumably. My footnote.

and weakens the sentence, whereas active voice is direct, succinct and more forceful. Compare “Patients were observed by two people for signs of abnormal behaviour” [5, p 49] with “Two people observed the patients . . . ” [5, p 49].

7. *Use of imprecise words.* Do not use words like “quite”, “some”, “considerable”, “a great deal”, etc. in scientific writing. It is imprecise and unhelpful to the reader. Be quantitative: you are writing an engineering thesis. Sometimes, you may wish to avoid numerical precision for some compelling reason. If you want to avoid writing “Fifty-two percent of the images were correctly classified”, do not say “The majority of the images were correctly classified”, but rather “Slightly over half the images were correctly classified”.

8. *Use of compound prepositions.* Debaters and politicians use expressions like “in the case of”, “in respect of”, etc., usually to gain time to think of a proper answer during a debate or a press conference. Such expressions dilute the force of the simple, direct statement: they have no place in your thesis.

9. *Multiple negatives.* A double negative, when used carefully, has impact or conveys just the right shade of meaning. Multiple negatives do not. They serve only to confuse and should be avoided. What does “not unreasonably inefficient” really mean? Anytime you cause your reader to backtrack or pause for mental breath to take in meaning, you have done yourself and your reader a disservice. (Remember the reflections on the transmission line in section 3.2.)

10. *Unfamiliar abbreviations and symbols.* Stick to SI units and prefixes. If you *have to* introduce a new unit called a *flip* make sure that you define it somewhere, introduce an abbreviation consistent with the SI system, use SI prefixes, and stick with your nomenclature all through.

4.6 Punctuation

Good punctuation makes reading easy. The simplest way to find out where to punctuate is to read aloud what you have written. Each time you pause, you should add a punctuation symbol. There are four major pause symbols, arranged below in ascending order of “degree of pause”:

- *Comma.* Use the comma to indicate a short pause or to separate items in a list. A pair of commas may delimit the beginning and end of a subordinate clause or phrase. Sometimes, this is also done with a pair of “em dashes” which are printed like this: —.

- *Semi-colon.* The semi-colon signifies a longer pause than the comma. It separates segments of a sentence that are “further apart” in position, or meaning, but which are nevertheless related. If the ideas were “closer together”, a comma would have been used. It is also used to separate two clauses that may stand on their own but which are too closely related for a colon or full stop to intervene between them.

- *Colon.* The colon is used before one or more examples of a concept, and whenever items are to be listed in a visually separate fashion. The sentence that introduced the itemized list you are now reading ended in a colon. It may also be used to separate two fairly—but not totally—independent clauses in a sentence.

- *Full stop or period.* The full stop ends a sentence. If the sentence embodies a question or an exclamation, then, of course, it is ended with a question mark or exclamation mark, respectively. The full stop is also used to terminate abbreviations like etc., (for et cetera), e.g., for (exempli gratia), et al., (for et alia) etc., but not with abbreviations for SI units.

The readability of your writing will improve greatly if you take the trouble to learn the basic rules of punctuation given above. For further guidance on punctuation, I recommend the books by Carey [36], Gowers [26], and Vallins [21, 22].

4.7 The I/We Active/Passive controversy

There is a pervasive belief that because scientific writing should be objective, one should avoid the first person singular pronoun 'I'[16]. This belief is embedded in another deeper conviction: scientific writing must be in the passive voice, again in the interests of objectivity, because the subject 'I' is thereby avoided. Some of those who hold these views are passionate about them. Others, are less dogmatic (see for example, Lindsay [5] and item 6 of section 4.5). So what is acceptable and what is not? Is there any "right way"?

I read the writings of Faraday, Maxwell and Rayleigh to get some light on the matter, and have discovered the following:

1. The first person singular pronoun, 'I', is used by them liberally when they describe experiments they have themselves performed, or where they introduce new nomenclature, or when they refer to their personal conjectures or beliefs. I suspect that this practice springs from the times when papers were literally *read* at meetings of learned societies before they appeared in journals. The use of 'I' was both natural and authoritative in that context. Examples of the use of 'I' are given below:

   > Many bodies are decomposed directly by the electric current, their elements being set free; these I propose to call *electrolytes*. Water, therefore, is an electrolyte.—*Michael Faraday* in [37, p 113]

   > I have recently been engaged in describing and defining the lines of magnetic force . . . *i.e.* those lines which are indicated in a general manner by the disposition of iron filings or small magnetic needles, around or between magnets; . . . —*Michael Faraday* in [38, p 407]

   > I first observed this peculiarity of my eyes when observing the spectrum formed by a very long vertical slit. I saw an elongated dark spot running

[16] The plural, 'we' somehow seems more acceptable, perhaps because it has royal connections!

> up and down in the blue, as if confined in a groove, and following the motion of the eye as it moved up or down the spectrum, but refusing to pass out of the blue into other colours.—*James Clerk Maxwell* [39, p 435]

> It is now, I believe, generally admitted that the light which we receive from the clear sky is due in one way or another to small suspended particles which divert the light from its regular course.—*Lord Rayleigh* [40, p 87]

2. The first person plural pronoun, 'we' is used when stating facts, assumptions or previously derived results; in (mathematical) proofs; and especially in textbooks where a didactic tone is normal. The use of 'we' conveys the impression of a dialogue between writer and reader: something that is lacking with 'I'. Here are some examples:

   > When we turn to radiation phænomena, then we obtain the highest proof, that though nothing ponderable passes, yet the lines of force have a physical existence independent, in a manner, of the body radiating, or of the body receiving the rays.—*Michael Faraday* [38, p 409]

   > We have used the phrase Lines of Force because it has been used by Faraday and others. In strictness, however, these lines should be called Lines of Electric Induction.—*James Clerk Maxwell* [41, p 98]

   > We have seen that the electrical charge on the surface of the glass is attracted by the rubber.—*James Clerk Maxwell* [41, p 318]

   > The symmetry also requires that the intensity of the scattered light should vanish for the ray which would be propagated along the axis; for there is nothing to distinguish one direction transverse to the ray from another. We have now got what we want.—*Lord Rayleigh* [40, p 89]

3. Passive voice is used in textbooks and in describing facts, and experiments done by others, or where it does not matter who did the experiments:

   > There was also another effect produced, especially by the use of large electrodes, which was both a consequence and a proof of the solution of part of the gas evolved there. The collected gas, when examined, was found to contain small portions of nitrogen. This I attribute to the presence of air dissolved in the acid used for decomposition.—*Michael Faraday* [37, p 127]

   > In each cell the copper plate is placed horizontally at the bottom and a saturated solution of sulphate of zinc is poured over it.—*James Clerk Maxwell* [41, p 397]

> There are two methods by which the pitch of a resonator may be determined without the use of a stream of air. The simplest, and in many cases the most accurate, method consists merely in tapping the resonator with the finger or other hammer of suitable hardness, and estimating with the aid of a monochord the pitch of sound so produced.... The other method is one of which I have had a good deal of experience, and which I can rely upon to give results of moderate accuracy. It consists in putting the ear into communication with the interior of a resonator, and determining to what note of the scale the resonance is loudest.—*Lord Rayleigh* [40, p 320]

It is clear that some very eminent scientists had no hesitation in using the first person singular pronoun "I" to describe what they did, perceived or inferred. This usage is direct and is preferable to the passive voice, especially when used to describe what *you yourself* did. If, for modesty or other reasons, you are uncomfortable with using the pronoun "I", use the passive voice instead, but *not* the first person plural pronoun "we", which is inappropriate for two related reasons:

1. You are describing work that you have *individually* done rather than some *collective* effort for which the plural number would be apt.

2. The University regulations are clear, especially for the PhD thesis, that *your original* work and contributions must be clearly distinguished from that of others [2]; again the plural number would be incorrect when describing this work.

4.8 Examples of good writing

I now present two examples of good scientific writing with some commentary:

> An atom is a body which cannot be cut in two. A molecule is the smallest portion of a particular substance. No one has ever seen or handled a single molecule. Molecular science, therefore, is one of those branches of study which deal with things invisible and imperceptible by our senses, and which cannot be subjected to direct experiment.—*James Clerk Maxwell* [39, p 361]

This is one of the founding fathers of the kinetic theory of gases holding forth on his home ground. These are the opening lines of a paper entitled *Molecules*, originally delivered before the British Association and published in *Nature*, Vol. VIII.

Maxwell uses the etymology of the word atom—from the Greek *atomos*, which means "not cuttable"—to define it clearly and directly. The expression "cannot be cut in two" is more picturesque and powerful than the usual textbook definition, "smallest indivisible particle", that we have been brought up on. He then progresses to molecules and provokes our *interest* in what these mysterious, invisible, imperceptible entities might be. We are left anticipating what ingenious experiments he might have devised to demonstrate the existence and properties of molecules. If you can draw your reader into your work like this, you have written a good thesis.

Now for the second example:

> A structure is an arrangement of particles, such as atoms, molecules, or ions. For example, a crystal is a definite structure. It is distinct from a gas, a liquid, or even a splodge[17] of butter, because in these the arrangements of particles are indefinite. Whereas in a crystal we can be sure to find a particle at some definite location relative to another, . . . in the "structureless" states of gases, liquids, and amorphous solids, the relative locations of particles are indefinite . . .
>
> We can summarize these remarks (and sow the seed for the generalization) by saying that the particles of crystalline solids are arranged *coherently*: the locations are *correlated*. In contrast, in gases (and to a smaller extent in liquids) the locations are uncorrelated. The idea that *structure signifies coherence,* with orderly regiments of particles, whereas *lack of structure signifies incoherence,* with a hodge-podge of locations, neatly captures solids as structures but allows gases to escape as structureless.—*Peter Atkins* [29, pp 179–180]

This is a fine example of leading the reader from the known to the unknown, progressively increasing the complexity of ideas. Atkins paints a picture in words, first relating structure to regularity in position. Then he moves on to the more mathematical and subtler concept of coherence and relates it to structure. The last sentence summarizes and binds together the three ideas: structure, positional regularity and coherence. The parenthetical statement "sow the seed for the generalization" again keeps the reader anxiously waiting for the rabbit out of the hat.

4.9 Spelling and grammar

Check the spelling of all words in your thesis, *including those in your bibliography*, using a good spelling-checker. Use Australian or British spelling consistently throughout. There is some confusion about which spelling is correct : "organize" or "organise". British usage *allows both* [26, p 239] where appropriate, as in this case. The only exceptions are words like "surmise" which are never spelt with a "z" at all. Be consistent, once you have made your choice and do not mix "organize" with "organise" in your thesis. Note also that most spelling-checker programs are unaware of the advice of authorities like Gowers [26]. If your spelling-checker does not pick up repeated words like "the the", write a simple program to warn you of them. Check also that you have not written "and" where you meant "an" and vice versa. Such errors will not be trapped by a spelling-checker. Be careful with grammar-checkers: I do not trust them.

If there are glaring spelling errors in your thesis, examiners will get the impression that it is "poorly finished" and will not rate it highly for presentation. Time spent in checking spelling and grammar is therefore time well spent.

[17] The use of a colloquial expression like "splodge" is permissible because the extract is from a book written to popularize science.

5 Style: Layout

The layout is the packaging for your thesis. A pleasing font and adequate margins make your thesis visually attractive. The convention is to choose a font with serifs (e.g., Times Roman) for the main text and a sans serif font (e.g., Helvetica) for text *inside* diagrams. All figure captions should be in the same font as the main text, preferably at one size smaller. The details of thesis layout are considered next.

5.1 Format

The regulations governing size of paper, size of margins, etc., vary with Department and University. At UWA, the regulations for an Engineering thesis are in harmony with the layout of the PhD thesis, where an extra left margin should be allowed for binding the thesis. At present, these regulations are:

> Theses are not restricted to one volume. They should be double or one and a half space typed on A4 paper with a left hand margin of 4 cm. There should be a 2 cm margin on all other edges. Typing on both sides is encouraged, and margins should be mirrored accordingly. [2].

The actual regulations may vary with time and the interested student is referred to the web site [2].

5.2 Word Processor vs Markup Language

Twenty years ago, theses were typed on typewriters and diagrams drawn by hand. This has changed with the advent of personal computers. You now type your own thesis at a computer terminal and use a word- or document-processing program to produce letter-perfect output. Microsoft Word and Corel WordPerfect are examples of WYSIWYG [18] word-processing programs, while TeX and LaTeX are examples of markup languages used in a document-processing system. If you do not know the difference between the two, you should browse the web and find out, before making an informed choice about which to use. I shall refrain from advising because I have a marked preference.

5.3 Diagrams, Graphs and Tables

By its very nature, scientific writing includes the *judicious* use of diagrams, graphs and tables. When do you present your results using a graph and when do you tabulate them?

A table invokes an expectation of regularity. So present dull, unremarkable data (that must nevertheless presented) in a table. Make sure that your variables are in different columns. Your rows for any given column should represent different observations of a given variable.

[18] What You See Is What You Get

A graph should be reserved for exciting findings or interesting, but unexpected results. Trends, departures from trends, dramatic behaviours of variables, etc., are good candidates for graphs.

Caption all diagrams, graphs and tables so that they may be read by themselves, independently of the main text, by a reader who wants only to skim your paper. It is discourteous to embed the explanation or commentary for a diagram or graph somewhere in the text and let the skimmer hunt for it.

Refer in your text to every diagram, graph and table, especially in the sections where you present and discuss your results.

The ready availability of graphical software should not entice you into presenting everything indiscriminately in pictorial form. Emphasis is rightly gained with sparing and selective use; and this applies to the use of diagrams, graphs, italics and bold typeface.

Three books that give helpful guidance on presenting diagrams, graphs and tables are [18, 42, 43].

5.4 Table of Contents, Bibliography and Index

There are facilities to generate the table of contents, bibliography and index automatically using word- or document processing programs. Learn how to use them and unburden yourself from the bookkeeping that goes with manually numbering references, figures, etc. You have more than enough on your plate, writing a good thesis, to fritter your attention away on such minutiae.

6 Conclusions

Writing a thesis well is simple if you know how. There are three aspects: structure, substance and style, but all three are entwined.

Start at the beginning by keeping good records. Understand what it is you are doing and why. Be clear what story you are going to tell. Keep the hypothesis to the fore always. Stick to the thesis structure you have been given.

Start writing your Experimental Chapters first. If you have done a Literature Review, write it next. Then complete the rest: Conclusions, Introduction and Summary, in that order. The other bits and pieces like the Appendices may be written as you go along.

Think, plan write, revise. Think clearly and write carefully. Clarity, precision and brevity are the three watchwords. Leave no gaps in the chain of logic or ideas you express. Avoid verbiage. Avoid clutter. Develop your own writing style by careful reading and even more careful writing. Polish what you have written by repeated reading and revision. Ask your supervisor to critique your thesis draft and amend it accordingly.

Enjoy writing your thesis and good luck!

7 Acknowledgements

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References

[1] D. Thompson, ed., *The Concise Oxford Dictionary of Current English*. Oxford, UK: Oxford University Press, 9th ed., 1995.

[2] The University of Western Australia, "Doctor of Philosophy Regulations." [web page], 30 August 1999. `http://www.acs.uwa.edu.au/research/phd/regs.html` [cited 29 February 2000].

[3] Honours Working Party, "Honours Working Party Report: 30 June 1999 (Amended 14 July 1999)." [web page], 10 August 1999. `http://www.acs.uwa.edu.au/reg/internal/sec/hwp/6.htm` [cited 29 February 2000]; Internal report of The University of Western Australia.

[4] The University of Western Australia, "PhD Examination Procedures." [web page], 13 January 2000. `http://www.acs.uwa.edu.au/research/phd/exam.html`; [cited 29 February 2000].

[5] D. Lindsay, *A Guide to Scientific Writing*. Melbourne, Australia: Addison Wesley Longman Australia, 2nd ed., 1997.

[6] R. Barrass, *Scientists Must Write: A guide to better writing for scientists, engineers and students*. London, UK: Chapman & Hall, 1991.

[7] P. B. Medawar, *The Strange Case of the Spotted Mice and other classic essays on science*. Oxford, UK: Oxford University Press, 1996.

[8] K. F. Schaffner, *Nineteenth-Century Aether Theories*. New York, USA: Pergamon Press, 1972.

[9] L. Carroll, *The Annotated Alice: Alice's Adventures in Wonderland and Through the Looking Glass*. Harmondsworth, Middlesex, UK: Penguin Books, 1978. Illustrated by John Tenniel; with an Introduction and Notes by Martin Gardner.

[10] M. Faraday, *Faraday's Diary: Being the Various Philosophical Notes of Experimental Investigation made by Michael Faraday during the years 1820–1862*, vol. II, Aug 25 1832–Feb 29 1836. London, UK: G Bell and Sons, 1932. edited by Thomas Martin.

[11] M. E. Van Valkenburg, *Network Analysis*. Englewood Cliffs, NJ, USA: Prentice-Hall, 3rd ed., 1974.

[12] B. P. Lathi, *Signals, Systems and Communication.* New York, USA: John Wiley & Sons, 1965.

[13] G. D. Gopen and J. A. Swan, "The science of scientific writing," *American Scientist*, vol. 78, pp. 550–558, 1990.

[14] Y. Attikiouzel, "Writing the PhD Thesis." Private verbal communication, as the author's PhD supervisor, Centre for Intelligent Information Processing Systems, Department of Electrical and Electronic Engineering, The University of Western Australia, Nedlands, WA 6907, Australia, 1993–1996.

[15] D. Lindsay, "Writing and Publishing in Scientific Journals." Staff Development Programme entitled "Writing and Publishing in Scientific Journals" organised on 3 June 1999 by the Centre for Staff Development, The University of Western Australia, Nedlands, WA, Australia, 1999.

[16] P. Hartmann, R. Fraser, and P. Maddern, "The characteristics of a good thesis." Discussion during Staff Development Programme entitled "Supervising Postgraduate Students" organised on 29 March 1999 by the Centre for Staff Development, The University of Western Australia, Nedlands, WA, Australia, 1999.

[17] T. Buzan and B. Buzan, *The mind map book.* London, UK: BBC Books, revised ed., 1995.

[18] D. Holtom and E. Fisher, *Enjoy Writing Your Science Thesis or Dissertation!: A step by step guide to planning and writing dissertations and theses for undergraduate and graduate science students.* London, UK: Imperial College Press, 1999.

[19] M. R. Schroeder, *Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise.* New York, USA: W H Freeman, 1991.

[20] E. M. Phillips and D. S. Pugh, *How to get a Ph.D. : a handbook for students and their supervisors.* Buckingham, UK: Open University Press, 2nd ed., 1994.

[21] G. H. Vallins, *Good English: How to Write It.* London, UK: Andre Deutsch, 1964.

[22] G. H. Vallins, *Better English.* London, UK: Andre Deutsch, 1955.

[23] G. H. Vallins, *The Best English.* London, UK: Andre Deutsch, 1971.

[24] R. A. Day, *Scientific English: A Guide for Scientists and Other Professionals.* Phoenix, AZ, USA: Oryx Press, 1992.

[25] M. H. Manser, ed., *Bloomsbury Guide to Better English.* London, UK: Bloomsbury, 1994.

[26] Sir Ernest Gowers, revised edition by Sidney Greenbaum and Janet Whitcut, *The Complete Plain Words.* London, UK: Her Majesty's Stationery Office, 3rd ed., 1986.

[27] M. Cutts, *The Plain English Guide: How to write clearly and communicate better.* Oxford, UK: Oxford University Press, 1996.

[28] P. W. Atkins, *Molecules.* New York, USA: Scientific American Library, 1987.

[29] P. W. Atkins, *The Second Law.* New York, USA: Scientific American Library, 1984.

[30] H. J. Morowitz, *Entropy and the magic flute.* New York, USA: Oxford University Press, 1993.

[31] J. Joyce, *Finnegans Wake.* London, UK: Faber and Faber, 1949.

[32] G. Lernout, ed., *Finnegans Wake: Fifty Years.* Amsterdam, The Netherlands: Rodopi, 1990.

[33] T. J. Rice, *Joyce, Chaos, and Complexity.* Urbana and Chicago, IL, USA: University of Illinois Press, 1997.

[34] N. C. Barford, *Experimental measurements : precision, error, and truth.* Chichester, Sussex, UK: Wiley, 2 ed., 1985.

[35] J. Topping, *Errors of observation and their treatment.* London, UK: Institute of Physics, 1956.

[36] G. V. Carey, *Mind the stop : a brief guide to punctuation with a note on proof-correction.* Harmondsworth, Middlesex, UK: Penguin, revised ed., 1971.

[37] M. Faraday, *Experimental Researches in Electricity.* London, UK: J M Dent and Sons, n.d. edited by Ernest Rhys.

[38] M. Faraday, *Experimental Researches in Electricity*, vol. III. London, UK: Richard Taylor and William Francis, 1855. Reprinted from the Philosophical Transactions of 1846–1852 with other Electrical Papers from the Proceedings of the Royal Institution and Philosophical Magazine.

[39] J. C. Maxwell, *The Scientific Papers of James Clerk Maxwell.* New York, USA: Dover Publications, 1965. Edited by W D Niven; two volumes bound as one.

[40] Rayleigh, John William Strutt, Baron,, *Scientific Papers by Lord Rayleigh (John William Strutt)*, vol. I: 1869–1881. New York, USA: Dover Publications, 1964. Six volumes bound as three.

[41] J. C. Maxwell, *A Treatise on Electricity and Magnetism*, vol. 1. New York, USA: Dover Publications, 3rd unabridged ed., 1954.

[42] R. A. Day, *How to Write and Publish a Scientific Paper.* Phoenix, AZ, USA: Oryx Press, 5th ed., 1998.

[43] H. B. Michaelson, *How to Write and Publish Engineering Papers and Reports.* Philadelphia, PA, USA: ISI Press, 1982.

Quick Reference Guide

- Writing a thesis well is simple if you know how.
- There are three aspects:
  - structure
  - substance
  - style

  but all three are entwined.
- Start at the beginning by keeping good records.
- Understand what it is you are doing and why.
- Be clear what story you are going to tell.
- Keep the hypothesis to the fore always.
- Stick to the thesis structure you have been given.
- Start writing your Experimental Chapters first.
- If you have done a Literature Review, write it next.
- Then complete the rest:
  - Conclusions
  - Introduction
  - Summary

  in that order.
- The other bits and pieces like the Appendices may be written as you go along.
- Think, plan write, revise.
- Think clearly.
- Write carefully.
- The three watchwords are:
  - Clarity
  - Precision
  - Brevity

in that order.

- Leave no gaps in the chain of logic or ideas you express.
- Avoid verbiage.
- Avoid clutter.
- Develop your own writing style by
  - careful reading and
  - even more careful writing.
- Polish what you have written by repeated reading and revision.
- Ask your supervisor to critique your thesis draft and amend it accordingly.
- Submit your best effort as your completed thesis.