Ethical Issues in Conducting and Reporting/Presenting Research Work

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Preface

The release of this book is a part of the department's efforts to ensure compliance with ethical issues in conduct and communication of research work. A signed declaration covering these issues explicitly is required after the cover page in every report/thesis submitted in the department. A sample declaration is provided in 'Appendix B'.

The booklet has useful sections covering how to get into research. I believe these sections, remodeled in this release, will be useful for both younger and older members of the student community.

Sanjeev
August 29, 2016

Contents

Chapter 1

Ethical Issues

This section covers the ethical issues a researcher must be familiar with while carrying out and reporting research work.

Communication of scientific results to archival journals is about four hundred years old. The first archival journal, Philosophical Transactions of the Royal Society, was started in 1665! Science has since then flourished and grown by leaps and bounds. Archival journals have played a key role in this growth by facilitating scientists to build on earlier works of fellow scientists and use their results as building blocks to create new knowledge structures. A scientist can carry forward today the work of another scientist located at an impossible distance, or someone who might have retired or even passed away several decades ago.

Scientists collaborate to pursue things that have potential to do some good some where, without even being in contact with each other. Some others collaborate to unravel aspects of nature, yet unknown to man. If you pause to think, you will realize that this cooperatively is unparalleled among the species inhabiting the earth. A number of animal species are known to hunt together for food with an agreed upon strategy. This instance of collaboration is driven by the immediate reward of food. The mankind has evolved to such an extent that collaborative activity is seen every where. Organizations/companies/work places/factories/offices have people working together, according to an agreed upon plan, for livelihood as the reward.

When the reward is unclear, collaboration becomes difficult. A meeting held to find out the best possible way to control traffic on campus or Bangalore city, with all the experts in the audience, is unlikely to lead to a conclusion. A number of ideas may come up, but none may reach the stage of acceptance by all. The scientists on the other hand have been collaborating with all kinds of unknown scientists to make contributions (innovations, technologies, and discoveries) that have been shaping our lives and our future. The best ideas get picked automatically without any personality conflict! Isn't this amazing. If a similar mechanism existed by which the best ideas get picked for taking a group of people or a nation forward, I think it would be great! So what is it that keeps scientists going (some keep going forever) to contribute to the cause of science?

The key element behind this most successful human enterprise, that we have named "Science", is the "innate joy" of finding something new and sharing with the *world that you have found something new*. The "new" could be a set of laws that explains a lot of seemingly unrelated things (Newton's laws explained everything that moves, till the advent of quantum mechanics). The "new" could be unraveling to the world how nature works (cellular machinery through DNA and RNA). The "new" also applies to creation of things that did not exist before (the flying machine), or finding new ways to do the old things efficiently (for example calculations using early computers), in a cost effective manner so as to make the benefits reach the vast masses (large scale production of antibiotics).

The innate joy of sharing a new finding with the rest of the world, and the recognition, fame, and power that often accompany it, are the rewards that drive scientists, besides the salary drawn. The reward therefore is a mix of joy of sharing something new with others, recognition by others of the effort involved, and for some the accompanying fame and power as well. The ratio of these components in a reward evolves for a scientist with the passage of years.

Clearly, if all that is needed is to announce to the world that one has found something new, scientists will becomes synonymous in no time with quacks and science will become quackery. One of the reasons why science instead enjoys an exalted status in our society is due to the adherence of all those involved in this enterprise *to an unwritten ethical code*. Two key elements of this code are: (i) the honour system, and (ii) the ability of another individual to reproduce the results mentioned by reading the publication. The first element has encouraged individuals with certain inclination and temperament to get into scientific endeavours by picking up threads from an earlier time. The second element has kept malpractices in science at bay. An investigation which cannot be repeated independently in another part of the world is bound to be reported sooner than later in newer investigations in the field—a situation that no scientist ever wants to be in. On the other hand, when a new finding is independently validated and is perceived by fellow researchers as a contribution that advances the cause of science, the original author is already handsomely rewarded for the efforts undertaken. The department hopes that during your stay here, you will also contribute to "Science".

The unwritten code I mentioned above, the first element in particular–the honour system, has been violated at times deliberately as you might have read in newspapers and at other times inadvertently. In either case, it hurts the cause of science. And because science has become a highly revered enterprise today, it also hurts people, departments, and institutions where such violations occur.

Ethical issues come up at every stage of scientific work—during execution and when it is written up for the award of a degree (report or thesis) or publication (journal article, conference proceeding). Most of the material on ethical guidelines in this write up is taken from two sources: 'Handbook of Technical Writing' by Brusaw et al. (St. Martin's Press, 1993) and 'Scientific Papers and Presentations' by Martha Davis (Academic Press, 1997).

1.1 In the beginning ...

The foremost expectation from a researcher is a clear determination of what is already known in the literature on a given topic of interest. A new student starting his/her research work typically assumes that the World Wide Web is where all the information is present and 'Google' is the search engine, and if the search does not show any meaningful results, nothing is known about the topic at hand. It is the typical but erroneous conclusion. A number of scientific journal databases such as 'Chemical Abstracts', 'Compendex', 'Inspec', 'Indest', Web of Science, etc., and now Google Scholar (with 'Related articles' option) serve this need. The institute provides access to most of these databases directly and automatically through the web pages of these databases. The same can also be accessed through the computers located in NCSI (opposite to Digital Library) premises. Accessing hardbound volumes of 'Chemical Abstracts' to locate relevant publication, the old method, is still operational, I believe.

While the advent of fast computers and fast networks enables us to search journal databases sitting in our offices, we need to understand that computer cannot read our mind. We interface with it by giving it key words. Arriving at a good combination of *key words* is an art which is mastered with some intelligence and a little bit of trial and error approach. It is very important that one learns it early, and learn it well. Test out your ability by carrying out some searches for which you already know where the databases must point you to.

Annual reviews and review articles appearing in journals are good starting points, but this is where it must stop. There is a tendency among us to just read a few review articles, and get done with them. This is like visiting a monument, but only by going around without getting inside any part of it. There is a lot more that becomes visible when one goes near and inside, and this is what makes the building a monument. No peripheral view can give the same feel. Similarly, no review of a paper can reveal all that ONE might find in the original work oneself. Please recall that reviews are always written with certain objectives, in addition to mentioning a thing or two about a large number of papers published in a given period. The subjective decision making of scientists writing a review article is always there.

The review articles should be mostly used to find out what needs to be studied in detail for the broad objectives a researcher is pursuing or gets interested in after reading some preliminary material. This approach is useful for those wanting to find out for themselves the unresolved questions in a field and the outstanding challenges in it, perhaps in an effort to get started in their research with a challenging unsolved problem. The next paragraph offers some guidelines for arriving at a topic for detailed consideration.

When a scientific investigation is presented to the science community, the latter, based on the honour system in practice, expects it to be both *new* and *original*. The first one means that the observations/results/findings are not already known in the literature, and the second one means that the approach used in the investigation has some original elements in it. This requires an investigator to closely search through the related body of work for important findings/breakthroughs (and cite those while simultaneously giving credit to the authors/researchers in writings and presentations) so as to explore the unexplored (and there are many varieties of what we call unexplored) and to provide new findings, when they come around, a perspective.

Comprehension of the material already published in topic/area of one's interest defines one as a PhD scholar as much as the new knowledge one generates in thesis work. The former is acquired slowly, with a lot of patience and hard work. Knowing salient features of important works in one's field combined with an in-depth understanding of every aspect of some of them is as important as the original contributions made in the thesis. If one is going to work on developing alternative model/theories, one should understand the other competing models/theories. These practices allow one to have an objective assessment of one's own contribution.

A critical assessment and cogitation of the past work often leads to new ideas and new possibilities. The experience shows that it is this capability that imparts the maximum confidence to a researcher and allows him/her to experience "the joy of research" first hand. Unfortunately, this is also among the least developed competencies in a researcher. One needs to develop the habit of making notes of what one comes across at this stage in their own words so as to not fall prey to plagiarism. A careful analysis of the arguments presented in published works to drive home conclusions, derivations of expressions presented in earlier works, looking out for the hidden assumptions in experimental or theoretical arguments, and unraveling of limitations of a model/theory/experimental technique teach a lot to a researcher, and also help in evolving a researcher into one with great insights. At this stage, one also learns to appreciate new ideas introduced in the past, determine who originated them, and most importantly what kind of experimental evidence and reasoning led to the birth of those ideas!

1.2 Continuing on

Having decided upon what one wishes to explore, the early moves must be planned with care and caution. The excitement of jumping into research can make one treat certain aspects/details as irrelevant, but these can come back later forcing one to either redo the same exercise, or discard the effort altogether as repeatablity of the investigation is not guaranteed.

When one carries out experiments in lab, as far as possible, only standard apparatus/equipment should be used and the parameters that can potentially influence the outcome should be controlled for reproduction of results at any other place, at any time. For example, letting a hot flask cool for five minutes before adding reagent C is not a reproducible step. In a different lab, the same flask may cool to different extents, because of the different ambient temperature and humidity, evaporative cooling, fan speed, flask shape and wall thickness, etc. A better option is to state the extent of cooling required in terms of specified end value of temperature. If one is synthesizing a material for its interesting characteristics, a number of intermediate steps which are obvious to an experimentalist such as leaving a precipitate in an oven to dry it need to clearly spelled out. In this case, oven temperature and duration of drying need to be stated, unless you have varied them to conclude that they have no influence.

The experimental data must always be collected without any preconceived notion of what it should look like. No experimental data should ever be dropped just because it does not fit the hypothesis/theory you are trying to validate/invalidate. In case of doubt, repeat the experiment, but report all the repeated trials. You can drop an experimental data only when you have detected an error in your experimental method or measurement technique. Till a clear cause for error in experimental data is established (after carrying out experiments under controlled conditions repeatedly), all the data, whether agreeing with your expectations or not, are to be treated with *equal respect* and reported as such, with the accuracy of the measurement brought out explicitly.

You should also preserve the experimental data in its most original form. For example, to predict pressure drop for pipe flow, you will need to know pipe diameter, flow rate, and density and viscosity of the fluid at room temperature. If you are using a capillary viscometer to measure viscosity, you should report efflux time and variation in it when you repeat it at least three times. Reporting directly the value of viscosity, estimated by using average efflux time with some formula hides accuracy, and sources and types of errors in measurement. Reporting of room temperature at the time of measurement is important. This allows your values to be compared with values measured by others using different instruments.

The reporting of raw data is essential in investigations where the observations are not understood quantitatively. For the example mentioned above, you could be tempted to plot predicted value of ΔP against the measured value of ΔP to show the efficacy of your formula, theory, or model, if the points fall on a straight line of slope unity, passing through the origin. The data reported in this fashion however does not allow anyone else to use your measurements to improve upon the existing theories as flow rate, pipe diameter, and other variables need to be known before a new theory can be tested. Such actions, whether deliberate—to support your incomplete theory to be published later—or otherwise, do not serve the cause of science.

Never fabricate or plagiarize experimental data and predictions. There is nothing is more damaging than this for the integrity of the student, the supervisor(s), the department, and the institute where this occurred. To keep quiet when you know someone is indulging in such a practices is an offense because it affects the academic integrity of everyone involved and the image of the country. For example, I have all forgotten about a high profile case of this nature, but still remember the name of the country!

Before we close, it is worthwhile to recall that science has progressed phenomenally because many great minds have worked passionately both for the love of science and personal glory. The passions however never came in the way of objective assessment of their work. More importantly, self-glory never blinded them to indulge in unethical practices. Except for a few aberrations, self-regulation has achieved for science what regulation and policing have failed to do in many other fields.

1.2.1 During the writing stage

Knowing the difference between ethical and unethical practices in technical writing requires an in-depth understanding of the *honour system*, *plagiarism*, *paraphrasing*, and *quotation*. These concepts are defined below (quoted directly from Brusaw et al.).

1.2.1.1 The Honour System

To follow the honour code is to give credit to the earlier investigations (and through them investigators) which allowed you to get started with the thread that you followed and whose findings helped you in reaching your own conclusions. This is also known as standing on the shoulders of others, or more famously what Issac Newton wrote “If I have seen further, it is by standing on the shoulders of giants”, and in a lighter vein “a dwarf on the shoulders of a (concealed) giant can claim to see farther than the giant himself, but the world will sooner than later discover the (concealed) giant”.

The honour system expects an investigator to disclose parallel lines of thinking process (also called competing hypothesis) in the literature on a given subject. A claim of priority (be the first one to do or find something) based on ’no’ showing up in one database for one combination of key words is a recipe for disaster. That the findings are new must be established by you to the *best of your ability* with an exhaustive search of the journal databases. An incorrect claim normally makes it harder for every one involved to carry on normally.

1.2.1.2 Plagiarism

> “To use someone else’s exact words without quotation marks and appropriate credit, or to use the unique ideas of someone else without acknowledgment, is known as plagiarism. In publishing, plagiarism is illegal; in other circumstances, it is, at the least, unethical. You may quote or paraphrase the words or ideas of another if you document your source. Although you need not enclose the paraphrased material in quotation marks, you must document the source. Paraphrased ideas are taken from someone else whether or not the words are identical. Paraphrasing a passage without citing the source is permissible only when the information paraphrased is common knowledge in a field. (Common knowledge refers to historical, scientific, geographical, technical, and other type of information on a topic readily available in handbooks, manuals, atlases, and other references.)”

Please note that the above applies to every type of material used in preparing a document/presentation. The material could be as little as a nicely constructed sentence or a couple of paragraphs, ideas, experimental data, graphs, theoretical predictions, sketches, cartoons, schematics, figures, etc., and this could be taken from any source such as a book, journal article, thesis, report, web page on internet, newspaper, etc. If material is taken from someone through verbal or private exchange of letters and e-mails, it still needs to be cited appropriately as 'Private Communication' from that person, but after taking his/her consent for citing the source in a work meant for publication. For example, while discussing your project problem, if a new idea is given by a friend of yours, you should either cite it (if he/she permits) or acknowledge his contribution by adding an 'acknowledgement' at an appropriate place in the report. Input from your research supervisor is, however, not cited.

1.2.1.3 Paraphrasing

> "When you paraphrase a written passage, you rewrite it to state the essential ideas in your own words. Because you do not quote your source word for word when paraphrasing, it is unnecessary to enclose the paraphrased material in quotation marks. However, the paraphrased material *must be properly referenced* because the ideas are taken from someone else whether or not the words are identical.
>
> Ordinarily, the majority of the notes you take during the research phase of writing your report will paraphrase the original material. Paraphrase only the essential ideas. Strive to put original ideas into your own words without distorting them."

Changing a few words and phrases, or changing the order of the sentences to give the impression that the written text is different from the original and is paraphrased is still plagiarism. Exercise caution while paraphrasing to ensure that the original idea is not distorted by you. Nothing can be more unethical to attribute some idea to an incorrect source and then criticize it.

1.2.1.4 Quotations

> "When you have borrowed words, facts, or idea of any kind from someone else's work, acknowledge your debt by giving

> your source credit in footnote (or in running text as cited reference)[1]. Otherwise you will be guilty of plagiarism. Also be sure you have represented the original material honestly and accurately. Direct word to word quotations are enclosed in quotation marks."

Some of the examples of plagiarism are: (i) taking sentences, paragraphs, and typed equations from sources such as journal articles, books, reports, proceedings, theses, ME reports, and Internet, (ii) mixing copied portions, changing some of the words, and/or rearranging sentences to camouflage the source, (iii) picking sentences from various sources to form paragraphs, and (iv) copying verbatim whole sections sections such as *literature survey*, *methodology*, *theory*, etc., from a closely aligned thesis/report with the belief that your new findings are contained in the *Results and Discussion* section. You *must* carry out your own literature survey, write your own interpretation of previous works, theory or methodology after reading the relevant material, or quote from earlier reports or the relevant material using quotation marks. If you do not have access to an article (appeared in a language other than English, or in an inaccessible journal), but know about its contents through its review or references to its contents in another article, you can refer to this material but you must refer to both the articles.

Using figures, tables, and schematics from published sources (of any kind) without providing full citation to the source in the caption (just below/above the cited material) is an offense. Graphs and schematics can be reproduced after taking written permission from the copyright holder. You can alternatively re-plot/re-tabulate the same data and prominently cite the source as indicated above. Under no circumstances should you leave a reader with the confusion that this could be your data. The written permission from the author(s) in this case, although not necessary, is a desirable option. It also helps you establish contacts in your field. The same applies to the schematics—you can adapt (redraw, and make modifications as well) from a published source, provided you prominently cite the source.

When you use programs (code) written by others with or without modifications, the report/thesis must clearly bring this out prominently with proper references, and must also reflect the extent of modification introduced by

[1] In technical writing, credit is given by providing reference to the work you are borrowing from, right at that point in the running text.

you, if any. A modified program is never entirely yours. A program, which you write from scratch, does not require source to be identified. Identification of source in all other cases is absolutely necessary. Standard subroutines (even if public domain) used in your programs must be properly referenced. Although programs need not be appended to the thesis, they must be submitted to your research supervisor in hard copy and other media. Inclusion of a computational flow chart in your thesis is highly recommended, however.

The material presented in the thesis/report must be self contained. A reader must be able to reproduce your experimental, theoretical, computational, and simulations results based on the information presented in the thesis. Ideally, the information provided by you must be so complete that someone trying to repeat what you have reported can do so without ever feeling a need to clarify some issues/doubts with you. You can easily achieve this distinction in report writing if you consider yourself in the role of a person trying to repeat your experiments. You would immediately realize that a whole lot of detailed information that you always took for granted is now needed by you in your new role in order to repeat your experiments/simulations. You need not mention that vessels were cleaned ten minutes before the experiments or five hours and then kept in oven. But if you find, while repeating the experiments, that the results come out to be very different every time, then this may be an important detail. You may then want to mention that in an effort to get reproducible measurements, even this variable for kept fixed to some value such as 30 minutes.

You must mention the names and addresses of the suppliers whose chemicals/instruments were used in the work to allow a reader to setup an experiment. While discussing issues related to computation time, the hardware used must be specified accurately, using processor speed, etc.

Declaration

Ph.D. and M.Sc. theses are submitted along with a ‘thesis submission form’ where you make a declaration about the authenticity of the work and adherence to ethical guidelines. For ME reports and reports to be prepared for ‘Experimental Methods in Chemical Engineering, a similar declaration (shown in Appendix B, at the end) should be added after the title page of the report.

Chapter 2

Organizing Your Material

Engineers need to know how to communicate their ideas in writing. There are two ingredients needed to make a good report—use of appropriate language and structure or organization of report. In this section, we cover the latter.

The basic aim of a report is to communicate the objectives of the work carried out, the procedures used in sufficient detail so that the work can be reproduced, discussion of results, and conclusions. It should give a list of symbols used, and references that have been cited in the body of the report. It should have appendices that contain all the details of data, and an example of calculation of quantities that have been reported in the body of the report but that had to be obtained from the observations or raw data. Appendices should also contain other details relevant to the report but which would hinder the flow of presentation if they were included in the main body of the report. The inclusion of programs or Matlab scripts written to carry out simulations comes in this category.

The thesis should appear as a homogeneous body of work (different from compilation of manuscripts prepared for publication), organized in sections/chapters. There are two ways to organize material. If the whole work revolves around a single theme/problem, with various aspects of it studied, then the thesis necessarily has 'Abstract', 'Table of Contents', 'List of Figures', 'List of Tables', 'Introduction', 'Literature Survey', chapters covering experimental and theoretical details, 'Results and Discussion', 'Conclusions and Scope for Future Work', 'Nomenclature' (if needed), and 'References'. These chapters should appear in the same order. A report which consisting of only sections and subsections, and no separate chapters, need not have 'List of Figures' and 'List of Tables'.

We now address how a report/thesis could be structured:

1. First decide which are the major sections in the report. The first is usually 'Introduction', which explains what it is that you are studying and why. Then there are a few sections describing how you are approaching and solving the problem. Then, there is usually a section 'Results' describing the results, and then a 'Conclusions' section laying out the major conclusions and future directions. List out these sections explicitly.

2. List out all the sub-sections under each section. Usually, description of different techniques or approaches or experimental methods used form different sections. Results obtained from the different techniques or approaches form different sub-sections. Similarly, results in different parameter regimes form different sub-sections.

3. Next in the hierarchy is 'paragraph sentences'. Each paragraph should start with a sentence which clearly describes what is elaborated in the paragraph. This 'paragraph sentence' should be carefully constructed, should be grammatically correct, and should be listed under the appropriate section or sub-section. Each 'paragraph sentence' should contain just one idea which you would like to convey to the reader, while the rest of the paragraph is elaboration, or providing evidence (in the form of references), for this idea.

4. Once you have framed all the paragraph sentences, the rest of the report will almost compose itself. The rest of this section restricts itself to the composition of the sections, sub-sections and paragraph sentences.

If the whole body of thesis work comprises of several similar but nearly independent problems, these can then be covered in separate chapters. Each chapter in such a scenario consists of 'Introduction', 'Previous Work', other sections as required, 'Results and Discussion', and 'Conclusions'. The chapters can have their own 'Notation' and 'References' sections, or common 'Notation' and 'References' sections at the end. An overall 'Abstract' of the whole thesis, 'Table of Contents', 'List of Figures', 'List of Tables', and a chapter titled 'General Introduction' will precede chapters that contain independent pieces of work. The 'General Introduction' chapter will provide overall perspective, motivation, and rationale for addressing different problems. The individual chapters covering independent investigations will be followed by 'Overall Conclusions and Scope for Future Work' chapter at the end. In the case of common notation and common references for all the chapters, 'Notation' and 'References' will appear at the very end.

2.1 Introduction

The objective of the introduction is to convince the reader why he/she should take the trouble of reading your report. In order to do this, firstly, you yourself have to be convinced that it is worthwhile for the reader to read the report. Secondly, you have present an argument (similar to arguments presented in court, for example) to the reader as to why he/she should read the report. The argument should be robust and tight, with no digressions, and no loose ends, and every paragraph has to make a point.

1. The first step is to ask yourself the reasons why you are doing what you are doing. What convinced you that, firstly, the field is still evolving and there are unanswered questions to be resolved or new developments to be made, and secondly, solving this problem is going to make a difference. Are there industrial applications, new theoretical tools, new simulation tools, etc. which are facilitated by your work. Write down one 'paragraph sentence' for every reason why you think your work is useful, and could make a difference. It is not necessary for a long list of reasons; just two or three will suffice.

2. Next, you have to convince the reader that you have developed a definitive understanding of the *important developments* in the field of study. It is important to emphasize only the significant developments (unless you are writing a review article), because the reader will lose interest pretty quickly. Start with developments that are general, and then progress to developments that become more and more specific to the problem you are solving. Write down a paragraph sentence for each significant development.

3. List the unresolved questions in the field. Write down a paragraph sentence for each of the unresolved questions. Alternatively, list the possible new developments that can be expected.

4. What is/are the unresolved questions and/or the new developments that is the subject of your research? Write down a paragraph sentence for each of these.

5. Under each paragraph sentence, briefly elaborate on the procedure used in each of these. Each of these paragraphs should be linked to a section below where the complete details of the solution procedure is explained.

2.2 Theory and background

Some theory and background is needed to understand the subsequent sections of the report. For example, some theory may be needed to interpret results of the experiments performed. Similarly, some theory may be needed to obtain relevant quantities from the actual measurements made. Some background may be needed to motivate the particular measurements to be made to understand some phenomena or as an improvement over other measurements made in the past or reported in literature. All this is presented in this section.

2.3 Experimental methods

This section should contain all the details of the experiment. It is to be emphasized that sufficient detail should be given to permit a repetition of the experiment by someone else who reads the report. This section could further be subdivided into the following subsections.

1. *Apparatus* A description and a diagram of apparatus if it is not a standard item that can be bought in the market. If some components of the apparatus are bought, their model number, name, and address of the manufacturer should be given.

2. *Materials* A list of chemicals used along with the grade (LR, AR etc.) and manufacturer should be reported in this subsection.
3. *Methods* A description of the protocol or the procedure used to conduct the experiment should be given under this head.

2.4 Solution procedure

1. At the start of the solution procedure, it is important to state, in explicit detail, what it is that was known before, and what it is that you have newly developed. For every idea that was known earlier, which is being used in your work, write a paragraph sentence with references to earlier work.
2. Next, write down a paragraph sentence for each of the steps in the solution or development procedure. Do not write any equations at this stage; the equations will appear later as a part of the paragraph.
3. In the case of experimental work, list the various steps in the experiment in sequence, and write a paragraph sentence for each of these. A good way to do this is to think back to the sequence of steps in conducting the experiment, and writing down one paragraph sentence for each of these steps.
4. Where possible, use the same sequence for presenting the solution procedure/experimental procedure and for presenting the results. The heading for each section in the solution procedure/ experimental procedure should correspond to an equivalent heading for a sub-section in the results.

2.5 Results & Discussion

This section is the most important part of the report. It is here that the trends in the results obtained are discussed, and interpreted to reach conclusions.

The results could be reported in the form of tables or graphs or both as you see fit. If the quantities of interest are calculated from observations, often the raw data or observations can be reported in appendices along with a sample calculation.

Results are discussed in following order.

1. Trends that are important in the items reported in each table or graph are described. A relevant point here is the comparison between the trend observed against the errors involved in the data. A comparison with the previously reported results, where relevant, is also to be discussed here.

2. The trends are then tallied qualitatively in terms of what is expected on the basis of existing theories. If agreement is there, the experiments confirm the theory, and that is a conclusion that can be drawn.

3. Real fun could start if there is disagreement. The disagreement must be discussed, and justified. Is it due to some limitation in the measurement? If so, suggestions to improve the technique could be made. If it is not possible to justify the disagreement, what are its implications? Does it disprove some theory or show some limitations of existing theories? *Never throw away disagreements observed. Such quirky observations lie at the root of many significant discoveries. In fact, one should be very alert to such trends.*

2.6 Conclusions & Suggestions

The first part of this section is a summary of the conclusions to be drawn from the work. The conclusions should be brief and to the point. Was the experiment a success? Is the theory being examined valid? Or does it have a limited validity? What are the main trends that you want your reader to "take home"? Answers to these questions form the body of the conclusions.

Any suggestions for follow-up work are the next part of this section. These could consist of better ways of making the measurement, improvements in the apparatus or the methods, or the theory, etc.

2.7 References or Literature cited

Several books, papers and other material might have been referred to in the body of the report. There are several formats to cite the references in the body and in list added in a section titled "References" or "Literature cited". The citation style used in your must be identical to that followed by a respected journal in your field. This style should be followed consistently all through the thesis. The journal style chosen must ensure that names of all the authors with their initials, title of the article, names of editors for edited books or proceedings, chapter titles and chapter authors in case chapter authors are different from book authors, range of pages that contain the referenced material, and address of book publisher appear in the bibliography. You should not mix citation styles of several journals and create your own style.

If you are using LaTeX, it is highly recommended that you use `citep` and `citet` commands in conjunction with database file of references and an appropriate bibliography style file to cite references properly and automatically generate the list of references at the end of the report, or at intermediate stages, as the case may be.

The following conventions are generally followed to cite a reference. A reference is given in the body of the text by citing the last names of authors and the year in brackets. If there are more than two authors, the name of the first author followed by *et al.* is used.

1. Van Pelt (1985) and not Linus Van Pelt (1985) and not L. Van Pelt (1956)

2. Laurel and Hardy (1973) in case of two authors

3. Snoopy *et al.* (1956) and not Snoopy, Brown, and Schroeder (1956)

The following format is generally followed in listing the references. References are listed in alphabetical order. References should be listed with the last names of all authors in the order in which they appear in the reference cited. The names should be followed by the title of the reference. It should then cite the source in detail. The year should follow in brackets. A few examples are given below.

1. R. B. Bird, W. E. Stewart, and E. N. Lightfoot "Transport Phenomena", John Wiley, (2002)

2. S. Kumar, V. Ganvir, C. Satyanand, R. Kumar, K.S. Gandhi "Alternative mechanisms of drop breakup in stirred vessels", *Chem. Engg. Sci.*, **53**(18), 3269-3280, (1998)

Notice that in referring to journal articles, volume number is in bold font, issue number in brackets, the beginning and end page numbers, and the year in brackets.

2.8 Nomenclature

The symbols used, their meaning, and units are given in this section. An example is given below. It is customary to define the symbol in the main body of the report when it is introduced for the first time.

C^f	Concentration of the solute in the micelle- free layer, Kg/m^3

2.9 Appendix

Appendices can be ordered by labeling them as A, B etc. One appendix should contain tables of all the observations, and a sample calculation of various quantities. The other appendices can contain any other details which were not given in the main body but which you might want to report.

2.10 Quotation vs. Reference to Earlier Work

If reproduction of some text material available in a published work can enhance the value to your thesis, you can add it to your thesis in the form of quoted material or a quotation. Such material should be indented on both sides over and above the indentation used for the regular text. It should preferably be single spaced, and appear as a separate paragraph(s), whether short or long. The idea is to make such material stand out from the rest of the text that you have written. Clearly, too many quotations or quoted paragraphs are not desirable in a thesis which is an original piece of work. Not quoting a material taken verbatim from another source is however plagiarism. Paraphrasing and giving credit to the author(s) is more accepted way of referring to earlier works.

Chapter 3

Format for Thesis

This section presents departmental guidelines (requirements) for the format of your reports and theses. The thesis/report has to be prepared keeping in view that the copies submitted to the libraries or to your supervisor could be the only surviving copies containing your valuable results. Readability and longevity of the copy you prepare for library, and your supervisor and other students are therefore of paramount importance.

Good readability requires that there are no grammatical mistakes in the text. Minor grammatical mistakes are annoying irritants and distract a reader from progressing with the text without losing focus. Unnecessary use of italicized, underlined, and bold faced words in the text is also irksome; such usage must be kept to a bare minimum. The font size and font type used for headings should be just big enough to indicate a break in continuity; the heading should not dominate the layout of a page. The thesis should be easy to open and read.

The longevity of a thesis is decided by the type and the size of the paper you use for making copies of your thesis. Ideally, the thesis should be submitted on acid free paper, but a paper having 25-50% cotton content is acceptable. Submitting a thesis on copying paper is not acceptable, as this paper pales and the print fades with time. Even when the paper used is of acceptable quality, if a thesis requires effort to keep it open, as is normally the case with bulky theses, its binding is likely to become loose, and at some point even break. As time has gone by, printing and copying a thesis on non-standard paper has become quite difficult.

Based on these considerations, the following guidelines are being laid down to ensure that the theses submitted henceforth meet certain minimum standards with respect to the format.

3.1 Paper Size and Quality

Ph.D., M.Sc. (Engg), and Final M.E. Theses Bright white colour A4 size (210 mm wide and 297 mm long) should be used to print a thesis. The paper should weigh 80 GSM (grams per square meter) or more. Printing on both sides is preferred to save paper and to reduce the space required to archive thesis copies on shelves. For printing on both sides, the paper should be sufficiently opaque (with higher GSM)—the material printed on the reverse side should not be visible while reading the thesis under normal lighting conditions. A bulky thesis which cannot be opened easily even with double side printing will need to be submitted either using thesis size paper or in more than one volume. Please consult the faculty in charge about the acceptability of your proposal.

3.2 Font

A 12pt font should be used consistently throughout the text. Captions for tables and figures must be in smaller fonts, but not smaller than 10pt. The figure captions should contain enough information to understand the result presented therein, without having to read the text. (The legend and other pertinent information must be provided in the caption, not in the text of the thesis.)

3.3 Textwidth

The text width should be 5.5 – 5.75 inches for A4 size paper (so that each line has on an average 12-13 words). The text width on thesis size paper should be 6.0 inches.

3.4 Linespacing

The line spacing used should be the same throughout the document, and can be chosen to be between one and a half to double (so as to obtain 3 to 4 lines per inch). Under no circumstances should it be less than one and a half. If an equation, a set of equations, an expression, or a chemical reaction is to appear in a separate line in a paragraph, it should appear centered and with necessarily the same spacing around as with the other lines of the paragraph (even if they contain all text). The line after an insert such as this should not be indented. A new line is indented only when it opens a new paragraph.

The lines in captions for figures and tables, Table of Contents, List of Figures, and List of Tables can be single spaced, if desired.

3.5 Paragraphs

No paragraph should have its opening line at the bottom of a page. A clear, consistent, but not too large a separation must be provided between the paragraphs throughout the thesis.

3.6 Margins

A margin of 1.5 inches or more on the binding side, and a margin of 1 inch on all the other sides should be provided in the **final trimmed and bound thesis**. Nothing should appear in these margins, including page numbers, running head, etc. The page number should be on the top, near the outer edge of the paper, one inch from both top and the outer edge of the paper. The text at the top of the page should therefore begin at 1.5 inches from the top edge of the paper.

The header at the top must have ‘Chapter #’ (not chapter title) on one side (near to the binding edge) and page number on the other side. A ruler separating the running head from the text is not permitted. Since theses are rarely referred to read only a small subsection providing additional information in header distracts readers more than it helps. It also makes thesis look more cluttered.

3.7 Headings

You should structure your document in a way that allows (i) easy access to a block of information (like in reference material), and (ii) continuity in presentation, moving from one aspect to the next. You should give headings to all such blocks. They can be numbered only down to three levels—the first level being the chapter title itself. Both numbered headings and those without numbers can appear in the Table of Contents.

No heading can have a font size greater than 25pt. You are encouraged to use smaller fonts for headings, but not smaller than 12pt.

3.8 Figures and Tables

Floats (figures and tables) can be put along with the text on the same page, provided the text covers at least 50% of the bottom of the page, and there is a clear separation between the float and the running text. A horizontal line separating the two is not allowed. Instead, caption should be put in a smaller font (10pt), with extra margin on both sides, with enough white space (about 2 cm) between the float and the running text. Thus, if a figure or a table requires more than 40% of the page, no text should appear on this page. It should appear on a separate page, in the center.

In case more than one float appears on a page, enough white space (not less than 2 cm) should be provided between them.

All the floating objects (Tables and Figures) will be numbered and provided with captions, and necessarily referred to in the text. A floating object not referred to in the text is not part of the document and must be removed.

The figure/table should be as much standalone as possible. This permits a reader to access the information presented there without having to refer to the text. Usually, a descriptive caption that also contains explanation for the notation used in the float and the values of the relevant parameters suffice. The figures should be drawn with properly chosen line style and line thickness and symbol type and their size. The same selection should be maintained for all the figures, for consistency and uniformity. Tables require judicious placing of horizontal lines for clarity.

3.9 Sequencing and Page numbers

The thesis should consist of (i) an abstract not exceeding 350 words, (ii) acknowledgement (if desired), (iii) Table of Contents, (iv) List of Figures, (v) List of Tables, (vi) Chapters, (vii) Appendices, (viii) notation, and (ix) References in that order. You can add a small write up (about half a page) about yourself at the very end, titled 'Vitae'.

Pages up to the List of Tables should be numbered in Roman, at the bottom of the page. The actual material of thesis, starting from chapter 1 will be numbered in arabic, starting with page 1 for the first page of Chapter 1.

3.10 One Side vs. Two Side Printing

You can print the report/thesis either way. For two side printing, the paper should be opaque enough so that the material printed on the other side of a page is not visible while reading the thesis in normal lighting conditions. Also, if a page printed on both the sides is copied, the resulting copies should be of the same quality as that obtained by copying a page printed only on one side. All chapters, including Table of Contents, List of Figures, List of Tables, and appendices must start on a right side opening page (odd numbered). All the pages should be numbered, including the blank ones.

Appendix A

Tips on Writing

There are many good books available on writing. This section is a selection of material from Robert Day (How To Write & Publish a Scientific Paper: 5th Edition, 296 pp, Oryx Press 1998, ISBN: 1573561657) and some inputs from Professors K. S. Gandhi and V. Kumaran. I strongly recommend that you acquire a book that deals with science writing.

A.1 Structure of sentences

A.1.1 Simple sentences

Usually sentences describe what was done by whom. Thus, they have a subject, verb, and an object. The sentence is structured that way: subject, verb and object. An example is:

Yuvraj caught the ball.

The structure in Indian languages is slightly different. It is subject, object and verb. Thus, the usual construction of the above sentence in Hindi is

Yuvraj ne ball ko pakada.

Thus, though it slows us Indians down, it is good to formulate sentences

directly in English, rather than translate them from our mother tongues.

The above is an example of a simple sentence. As far as possible, it is best to use simple sentences. However, the subject or the verb or the object or all of them may have to be qualified. For example, Ganguly may be tired when he caught the ball, the ball might have been traveling fast, he might have caught it after a few attempts, and so on. The number of sentences will increase to express all the ideas if one is restricted to use only simple sentences. So we have compound sentences.

A.1.2 Compound sentences

In compound sentences, the "properties" of the parts of the sentence are mentioned. The group of words used to describe the properties are called qualifying clauses. The qualifying clauses can be full sentences or parts of a sentence. Look at some examples:

Ganguly, usually a reliable fielder, dropped the ball, though it was traveling slowly.
If glucose is added, the medium supports growth.

Position of clauses: The main problem in writing compound sentences, is proper positioning of the qualifying clauses. A lot of confusion is created if positioning is improper. Consider the following examples:

1. I knew a man with wooden leg named George. Who is George? The man or the wooden leg?
2. Look at the difference between following two sentences. *I almost wrote a cheque for $ 1000.* and *I wrote a cheque for almost $ 1000.*
3. *A large number of papers have been written on the cell walls of Staphylococci.* Were the papers written on cell walls or regular paper?
4. *Lying on top of the intestine, you can perhaps make out a thin transparent thread.* To see the thread, do you have to lie on top of the intestine?
5. *On analyzing the data statistically, the Salmonella infections were indeed rare.* Can Salmonella avoid getting infected by learning statistical analysis of data?

6. *I went to a town that was 20 miles away on Tuesday.* What is the distance on Friday?

Positioning of the qualifying clause is the essential issue. Rewrite the above to avoid confusion as an exercise.

Awkward and ambiguous construction: Positioning is not the only crucial issue. Awkward construction is another source of confusion. Such constructions often arise while aiming at being bombastic or flowery or poetic. At the cost of being even drearily simple, one should avoid decorative language. Look at the following examples.

1. *Chemical engineering is what he took his degree in.* One should prefer "He took his degree in chemical engineering."
2. *The paper concludes with a summary of the evidence indicating that A may be, under carefully limited circumstances, an effective agent against infections caused by gram-negative organisms.* As nothing is being said about what the carefully limited circumstances were, the reference to them is redundant and nothing is being communicated. It is sufficient if it is written as: "The trend suggests that *A* is effective against infections caused by gram-negative organisms."
3. *Rare diseases are not commonly encountered.* Of course! Delete the sentence.

Ambiguous construction arises when things are spelt out in a manner to lead to confusion. Often, it is used to create jokes.

1. This is from the cartoon strip"Tiger". The following conversation takes place between Tiger and Pumkin. T: It takes three sheep to make a sweater. P: Gee! I didn't know that sheep can knit!
2. Two hunters are out in the woods when one of them collapses. He doesn't seem to be breathing, and his eyes are glazed. The other guy whips out his phone and calls the emergency services. He gasps "My friend is dead! What can I do?". The operator says, "Calm down, I can help. First, let's make sure he is dead." There is a silence, then a shot is heard. Back on the phone, the guy says, "Okay, now what?"
3. *Ravi went to lunch. While having lunch, the reaction mixture exploded.*

A.1.3 Length of sentences

It is best to keep the length of sentences as small as possible to avoid confusion and inaccuracies. At the same time, one should avoid writing too many sentences to convey the same idea. Obviously, there is an optimum in the use between simple and compound sentences. This was discussed earlier. At the cost of repetition, another example is given.

As is well known, the tennis ball is made of rubber. The tennis ball is round in shape. More over it is yellow in color.

It is simply stated as “The tennis ball is a yellow, and round object made of rubber”.

A.1.4 Match of tense and person

The tense and person in the sentence much be matched. Consider the following examples.

1. Data *are* .... and not “Data is ...”
2. Table 4 *shows* ... and not “Table 4 show ...”
3. Tables 4 and 5 *show* ... and not “Tables 4 and 5 shows ..”
4. In the previous paper, we *treated* ... and not “In the previous paper, we treat ...”
5. Which is correct? A bunch of grapes (is, are) on the table.
6. Which is correct? A bunch of apples (is, are) on the table.
7. Which is correct? A series (number) of experiments (was, were) performed.

A.1.5 Punctuation

Punctuation helps a lot in delineating clauses when many of them are being used. Place them at the correct places. Look at the following examples:

1. *The system consists of an engine, tubing to bring fuel to cylinders and associated mounting bolts.* Is fuel being brought to the mounting bolts also? If not, we need a comma after cylinders. A better way is: "The system consists of an engine, associated mounting bolts, and tubing to bring fuel to to cylinders."

2. *He had a large head, a thick chest holding a large heart and big feet.* Should we not get feet off the chest?

3. A beautiful illustration of the importance of punctuation forms the title of a book "Eats bamboo, shoots and leaves". A giant Panda visited a restaurant. He ordered tender bamboo shoots. After he finished eating, the bill was brought to him by a bearer. The Panda got up, shot from a pistol and left. The bearer was shocked and to learn more about pandas, he looked up a dictionary. It said: Giant Panda: Eats bamboo, shoots and leaves.

4. Upper case letter should be used for the first word of any sentence.

5. There *is no space* **before** a full stop; there *is a space* **after** a full stop.

6. There *is no space* **before** a comma, semicolon or colon; there *is a space* **after** a comma, semicolon or colon.

7. There *is a space* **before** an open parenthesis '(', there *is no space* **after** an open parenthesis '('.

8. There *is no space* **before** an open parenthesis ')', there *is a space* **after** an open parenthesis ')'.

9. There is *no space* when two words are joined by a hyphen as in 'sub-section'.

10. Equations are a part of the text. After every equation, there should be a full stop (if it is the end of the sentence, and the following sentence starts immediately after the equation), or a comma (if the equation is a part of the sentence). Examine every equation to ensure it is a part of the text.

A.2 Some Thumb Rules

1. Sentences usually begin with an article; ‘The’ being the article which is most often missing at the beginning of sentences.

2. Never use ‘this’, ‘that’, ‘these’ and ‘those’ as pronouns, as in ‘This shows ...’, ‘That indicates ...’, etc. Always use ‘this’, ‘that’, ‘these’ and ‘those’ as adjectives, as in ‘This result shows ...’, ‘That experiment indicates ...’, etc.

3. Avoid passive voice and long sentences, such as ‘... it may be seen from these results ...’ or ‘... an examination of the patterns formed was carried out’. Use active and direct sentences, such as ‘... these results show that ...’ or ‘... the patterns formed were examined ...’ Examine every sentence you have constructed, and check if it can be framed in a more direct fashion.

4. Use ‘connecting words’ to relate a sentence to the previous one. For example, when a sentence is a consequence of the previous one, ‘thus’, ‘therefore’, and ‘consequently’ are appropriate at the beginning. When a sentence provides information in addition to that provided by the previous sentence, ‘moreover’ or ‘in addition’ can be used. When a contrary viewpoint is being expressed, use ‘alternatively’, ‘conversely’ of ‘however’. When a sentence summarizes what has been stated earlier, ‘in short’ or ‘in summary’ can be used.

Appendix B

Declaration

I/We certify that the report was written by myself/ourselves, and in writing the report,

1. experimental data collected/simulation results obtained by me/us have been presented without any bias, modifications, or alterations, and can be obtained by others using the information provided in the report.
2. I/we have not copied material from published/unpublished sources (reports, text books, papers, web sites etc.),
3. where material from any source was used, the source was given due credit by citing it in the text of the report and giving its details in the section on references, and
4. where material from any source was copied, it was put in quotation marks, and the source was given due credit by citing it in the text of the report and giving its details in the section on references.

Signatures of the authors.

The above declaration must appear on a single sheet, immediately after the cover page of the report/thesis.