Ethical Issues in Conducting Research Work
and
Guidelines for Preparing Report/Thesis

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Preface

The department faculty have for long felt a need to expose students to ethical and other issues involved in (i) executing scientific work of any kind, theoretical or experimental, (ii) writing it up for thesis/project report and communicating it to journals for its publication, and (iii) presenting it to others. This booklet is our partial response to this need. The first chapter deals with various ethical issues that the students must be aware of and must adhere to while conducting research work and presenting it to others in writing or orally. The second chapter presents the departmental guidelines (requirements) for the format of your reports and theses. The last chapter deals with the ideas on writing skills and guidelines for getting into the act of writing itself. This chapter is compiled from the material provided by Prof. K. S. Gandhi and Prof. Kumaran

It is **required to attach the declaration** in 'Appendix A' with your signatures in your report, immediately after the cover page as a separate page. Appendix A is available at the end of the this booklet.

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Chapter 1

Ethical Issues

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This chapter formally exposes you to various ethical issues that you must be aware of and must adhere to while conducting research work, and subsequently while writing it up for publication and presenting it to any audience.

The ethical issues discussed here are general and apply to all your work, your writing and your presentations. After more than three hundred years of journal reporting and building on others work to make further progress in science (an alternative to rediscovering wheel every time), the scientific community seems to have reached unanimity of the view that conducting scientific research and reporting it in ethical manner has served it very well in the past. Ethical practices evolved over this large span of time, if followed in spirit, offer protection to work/effort of the researcher as well as that of others. Scientific community judges your contribution and tries to build on it with the implicit assumption that ethical practices have been followed all along. Unfortunately, now with the proliferation of cut-and-paste culture (enabled by computers) and pressure to publish, there is a danger that these ethical issues will be bypassed. We hope that this booklet will help you to become a responsible member of the scientific community by exposing you

to what constitutes ethical conduct and what does not.

Your name normally appears explicitly on the documents you prepare and the presentations you deliver. You are, therefore, solely responsible for any breach of ethical norms in them. Later, when you will prepare documents for your employer/organization and make presentations on their behalf, your name may not appear explicitly, and yet the responsibility to follow these ethical norms will be yours alone. Irrespective of whether you are preparing a formal or an informal document/presentation and whether it is for internal or external circulation, the requirement to follow ethical norms at all stages remains unchanged. The department therefore strongly recommends that you imbibe these ethical guidelines at an early stage. They will become a part of you with some experience and practice, and you will begin to follow them unconsciously in years to come.

The format you are required to adhere to while submitting the work as MSc/PhD thesis or ME project reports as laid down in the second half of these guidelines is designed to help a reader focus on what you have to say instead of getting distracted by everything else. The format required for submitting reports in course CH206 titled 'Experimental Methods in Chemical Engineering' is the same as that for first ME project report, due after three months of work.

1.1 Ethical Issues

Ethical issues come up at every stage of academic work when it is being executed and later when it is written up as thesis, report, or a manuscript for publication in journals, or when it is presented as in technical talks. In the first part of this section, we deal with ethical issue that are involved while work is carried out. We then deal with many more issues that get involved when work is written up or presented to others. Most of the material on ethical guidelines in this writeup 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).

1.1.1 During the work stage

The first and foremost expectation from a researcher before (s)he undertakes research work on a given topic in an area is a clear determination of what has been done and reported in the open literature on the topic. It is desired that the researcher also undertakes a survey of closely related topics. When an investigation is reported or presented by you, the academic community assumes that you are presenting new work and that you have established to the *best of your efforts* that it is new. This determination ought to be made after an exhaustive search of journal databases such as 'Chemical Abstracts', 'Compendex', 'Inspec', 'Indest', etc. New students starting their research work increasingly assume (unfortunately without asking senior researcher and faculty members) that World Wide Web is where all the information is present and 'Google' is the search engine which helps one bring it out. If the search does not show any results, it is incorrectly assumed that no one knows anything about the topic being searched, hence the problem at hand it new. Nothing could be more devastating than relying on search results produced by Google to establish that one is working on a new problem. Journal databases available on computers located in NCSI premises, also accessible through their web page, are to be compulsorily used for this determination. Accessing hardbound volumes of 'Chemical Abstracts' was the old method, and I believe it can still be used in JRD Tata library. With the advent of fast computers and fast network links, there are now very powerful tools available to us that enable us to search journal databases by combining *key words* intelligently. This is an art which can be mastered with very little effort, and it is a must for carrying out new work.

Review articles written in recent past, which usually appear in reputed journals, edited books, and annual reviews, are good starting points to access relevant literature in your topic/area. Please make a habit to copy relevant material and maintain these copies in a file folder. There are instances of people cutting the original article from journal/book itself. This is highly deplorable. If you know of someone doing it, it is your ethical duty to report it to someone like the librarian or your own chairman. You can also report it anonymously.

Comprehension of material already published in topic/area of your interest is the next ethical practice that you would like to imbibe. Knowing the salient features of important contributions in area of your research in-

terest is a good research practice. If you are working on developing alternative model/theories, you should understand other competing models/theories. These practices allow you to have an objective assessment of your own contribution. Critical assessment of past work also often gives rise to new ideas and new possibilities, which you can use to augment your research activities. Experience suggests that this is perhaps the most inadequately acquired practice/capability of the many others that new researchers need to acquire in order to experience the joy that the world of research offers. You should begin to take notes on the material you read at this stage in your own words (so as to not fall prey to plagiarism), critically analyse the material, derive expressions on your own, look for implicit assumptions, inherent limitations of the model, theory, or the experimental technique. You should also learn to appreciate new ideas introduced in the past, determine who originated them, and most importantly what kind of evidence and reasoning led to the birth of those ideas.

Having determined that you are set to explore or probe something new, the academic community expects you to now move forward with care and caution and with very high ethical standards. Science has progressed because many great minds have worked passionately, but passions never came in the way of objective assessment of their own work while it was reported and presented.

When you carry out experiments, 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 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 report 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 obtained by using some formula and the average value of efflux time hides sources of errors and types of errors in the measurement, and the accuracy of measurement from the reader. Reporting room temperature at the time of experiment and when viscosity was measured are important, even when the two temperature are the same. This allows your values to be compared with values measured by others using different instruments.

Reporting raw experimental data is absolutely essential on another count as well. 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. Notice that experimental data reported in this fashion will not allow anyone else later to use your experimental data to test new theories, as it requires flow rate, pipe diameter, and all the other variables to be known. This certainly does not serve the cause of science, whether it is done inadvertently or otherwise.

Never fabricate or plagiarize experimental data and predictions. Nothing can be more damaging than this for the integrity of the student and the supervisor(s) involved, and the integrity of the department/institute where such a breach of ethics occurs. To keep quiet when you know someone is indulging in such practices is also an offense because it affects the academic integrity of everyone involved—the department, the institute, and the country.

You should not take help from others/colleagues to do the assignments given in course work. Copying from other's assignment makes both parties liable for penalty.

Report writing stage in the experimental course (CH 206) is a group effort. All the members are expected to sit together, discuss among themselves, and then come up with their best effort at presenting experimental findings in terms of the structure (sections and subsections) of the report, plots and schematics to be used, construction of sentences, organization of paragraphs, and continuity in going from one paragraph to the next. Similar considerations apply to any group effort, e.g. group assignments given in some courses, etc. These assignments must be carried out by all the members of the group together and the final form of your response should be arrived at in the presence of all the members, with joint effort. Often, the motivation behind giving group assignments is to promote a healthy discussion among

students in small groups, or to present to them problems which require brain storming sessions to consider very many possibilities/complexities before a solution can be arrived. This is to be strictly adhered to by every member of a group.

1.1.2 During the writing stage

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

1.1.2.1 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.

1.1.2.2 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.

1.1.2.3 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."

[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.

The following are some examples of plagiarism: (i) without giving due credit, taking sentences/paragraphs from sources such as journal articles, books, reports, proceedings, theses, ME reports, and Internet, mixing them to camouflage the source, changing some of the words, or rearranging the sentences is plagiarism, (ii) picking sentences from various sources to form paragraphs, and (iii) copying with or without changes sections such as *literature survey*, *methodology*, *theory*, etc., from a thesis/report already submitted and closely aligned with your work. You must carry out your own literature survey, write your own interpretation of 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.

Taking experimental data, pictures, and graphs from others' work or from the internet without citing the authors or the website right in the caption of table, figure, and graph is a very serious issue. Graphs and schematics already published in a work can be reproduced after taking written permission from the copyright holder. You can alternatively re-plot the same data and prominently cite the authors in the figure/table captions as well as in the text; 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 to establish contacts in your field.

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 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, computa-

tional, 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 A, at the end) should be added after the title page of the report.

Chapter 2

Guidelines for Thesis/Report Format

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This chapter presents departmental guidelines (requirements) for the format of your reports and theses.

2.1 Structure of Report/Thesis

The thesis should appear as a homogeneous body of work (different from compilation of manuscripts prepared for publication), organised in sections/chapters. There are two ways to organise 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 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'.

If the whole body of thesis work comprises of several similar but nearly independent problems, each of these can be dealt with in a separate chapter. In such a case, each chapter should consist of 'Introduction', 'Previous Work', intermediate sections as needed, 'Results and Discussion', and 'Conclusions'. Each chapter can have its own sections covering 'Notation' and 'References'. All these chapters will have to be necessarily preceded by an 'Abstract' of the whole thesis, 'Table of Contents', 'List of Figures', 'List of Tables', and a chapter titled 'General Introduction'. The latter, in addition to providing overall perspective and other things, should provide motivation and rationale for addressing several different problems. The main body of the thesis will be necessarily followed by a separate chapter on 'Conclusions and Scope for Future Work'. In the case of common notation and common references for all the previous chapters, 'Notation' and 'References' will also appear at the end.

2.1.1 Quotation and 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.

2.1.2 References

The citation style used in your thesis 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 can be chosen by you but please 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.

2.2 Format for Thesis

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.

2.2.1 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.

2.2.2 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.)

2.2.3 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.

2.2.4 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.

2.2.5 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.

2.2.6 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.

2.2.7 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.

2.2.8 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.

2.2.9 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.

2.2.10 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.

Chapter 3

Report Writing

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The aim of this note is to present the basic ideas on report writing. Engineers should learn how to communicate their ideas both orally and in writing. Clear, simple and direct means of communication is the best. At least this is the view point adopted here.

There are two main components in writing a good report. The first is the language used. The second is the structure or organization of the report. In this note, both these will be covered.

3.1 Basic Rules of Writing

There are many good books that give guidance for writing. This section is a selection of material from the book by Robert Day (How To Write & Publish a Scientific Paper: 5th Edition, 296 pp, Oryx Press 1998, ISBN: 1573561657). Obviously, it is best if the book itself is read.

3.1.1 Structure of sentences

3.1.1.1 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 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.

3.1.1.2 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.*

3.1.1.3 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".

3.1.1.4 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.

3.1.2 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.

3.1.3 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 summarises what has been stated earlier, ‘in short’ or ‘in summary’ can be used.

3.2 REPORT

The basic aim of the report is to communicate the objectives of the work done, 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. We now address how a report/thesis could be structured.

3.2.1 Organising the report

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 chapter restricts itself to the composition of the sections, sub-sections and paragraph sentences.

3.2.2 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 emphasise 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.

3.2.3 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.

3.2.4 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.

3.2.5 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.

3.2.6 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.*

3.2.7 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.

3.2.8 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 list them in the section entitled "References" or "Literature cited". Choose any format and use it consistently. The following 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.

3.2.9 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

3.2.10 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.

Appendix A

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.