

Response of precipitation extremes to changes in temperature in the Indian subcontinent

Aditya Sengupta



Department of Earth and Atmospheric Sciences
National Institute of Technology Rourkela

Response of precipitation extremes to changes in temperature in the Indian subcontinent

*Thesis submitted in partial fulfillment
of the requirements for the degree of*

Master of Science

in

Atmospheric Sciences

(Specialization: Hydro-meteorological extremes)

by

Aditya Sengupta

(Roll Number: 420AS2068)

based on research carried out

under the supervision of

Prof. Naresh Krishna Vissa



May, 2022

Department of Earth and Atmospheric Sciences
National Institute of Technology Rourkela



May 10, 2022

Certificate of Examination

Roll Number: 420AS2068

Name: *Aditya Sengupta*

Title of Dissertation: *Response of precipitation extremes to changes in temperature in the Indian subcontinent*

We the below signed, after checking the thesis mentioned above and the official record book (s) of the student, hereby state our approval of the thesis submitted in partial fulfillment of the requirements of the degree of *Master of Science in Atmospheric Sciences* at *National Institute of Technology Rourkela*. We are satisfied with the volume, quality, correctness, and originality of the work.

Naresh Krishna Vissa
Principal Supervisor

Carl Friedrich Gauss
Member, DSC

Isaac Newton
Member, DSC

Dennis Ritchie
Member, DSC

Niels Bohr
External Examiner

Aryabhata
Chairperson, DSC

Varahamihira
Head of the Department



Department of Earth and Atmospheric Sciences
National Institute of Technology Rourkela

Prof. Naresh Krishna Vissa

Assistant Professor Grade-1

May 10, 2022

Supervisor's Certificate

This is to certify that the work presented in the thesis entitled *Response of precipitation extremes to changes in temperature in the Indian subcontinent* submitted by *Aditya Sengupta*, Roll Number 420AS2068, is a record of original research carried out by him under my supervision and guidance in partial fulfillment of the requirements of the degree of *Master of Science in Atmospheric Sciences*. Neither this thesis nor any part of it has been submitted earlier for any degree or diploma to any institute or university in India or abroad.

Naresh Krishna Vissa

Dedication

You may dedicate your dissertation in this page.

Dedication should be no more than one page.

You may choose your preferred font and size.

Signature

Include this page in the pretext page count,
but do not place a page number on it.

Declaration of Originality

I, *Aditya Sengupta*, Roll Number 420AS2068 hereby declare that this thesis entitled *Response of precipitation extremes to changes in temperature in the Indian subcontinent* presents my original work carried out as a postgraduate student of NIT Rourkela and, to the best of my knowledge, contains no material previously published or written by another person, nor any material presented by me for the award of any degree or diploma of NIT Rourkela or any other institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the dissertation. Works of other authors cited in this dissertation have been duly acknowledged under the sections “Reference” or “Bibliography”. I have also submitted my original research records to the scrutiny committee for evaluation of my dissertation.

I am fully aware that in case of any non-compliance detected in future, the Senate of NIT Rourkela may withdraw the degree awarded to me on the basis of the present dissertation.

May 10, 2022
NIT Rourkela

Aditya Sengupta

Acknowledgment

This section shows the essence of the student's journey during the course of the research work and the role of other individuals in shaping his/her academic life. Acknowledgments are non-consequential in that a student is not evaluated on them. An acknowledgment has typically three sections —

- *Reflection*: Narration of the student's journey through his/her research career.
- *Thanking*: Expression of gratitude to those who have helped in the student's journey.
- *Announcement*: Accepting responsibility for the work and/or dedication of the dissertation to someone. This in fact is a repeat of declaration and dedication pages.

October 07, 2016
NIT Rourkela

Avul Pakir Jainulabdeen Abdul Kalam
Roll Number: AyyPQwxyz

Abstract

Write the abstract of the dissertation followed by 3 to 7 keywords or phrases. An abstract is a micro dissertation. Both the dissertation and abstract should answer the following few questions —

- What was done?
- Why was it done?
- How was it done?
- What was found?
- What is the significance of the findings?

In the abstract section, one should answer the above questions in short paragraphs. The total length of the abstract should typically be limited to two pages.

Mention 3 to 7 keywords, phrases, or index terms in ***bold-italics*** separated by semicolons. These words should be carefully chosen in a manner that they convey sufficient information on what the dissertation is all about. These words help other researchers to search and find your work.

Keywords: ***KW₁; KW₂; KW₃; KW₄; KW₅.***

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Chapter 1

Introduction

A treatise advancing a new point of view resulting from research is one of the compulsory requirements of an academic degree of NIT Rourkela. Undergraduate students submit a project report in support of their candidature for B.Tech. degree. Similarly, Masters students submit theses, and doctoral students submit dissertations. Unless otherwise stated explicitly, henceforth in this document the word “dissertation” will be used as a synonym for “report” and “thesis”.

This document is intended to provide a guideline to students in the preparation of their dissertations. A dissertation is expected to have ethical standards and uniform format with readability. NITR will accept dissertation only in pdf format, which should be uploaded directly to the NITR dissertation submission web page for approval by supervisor. Templates to assist in formatting dissertation in \LaTeX is available in Academic -> Dissertation Template at the URL <http://nitris.nitrkl.ac.in>.

1.1 Dissertation Arrangement

Each dissertation must be arranged in the following serial order. Optional pages may not be included.

i. **Cover Page**

The cover page comprises the dissertation title, author’s name, and institutional details. This page is excluded from page number counter. A sample cover page design and spine design is shown in Figure 1.1.

ii. **Title Page**

The title page includes the title of the dissertation followed by submission month-year, department, degree, author’s name, and supervisors’ names. Include this page in the pre-text page count, but do not place a page number on it. The top margin on this page shall be 60mm. [Sample Included]

iii. **Certificate of Examination**

Include this page in the pre-text page count, but do not place a page number on it. If

the Chairperson of the DSC is the HoD then he will sign twice. The top margin on this page shall be 60mm. [Sample Included]

iv. **Supervisor's Certificate**

Two samples are given; Appropriate sample may be used depending on the number of supervisors. Include this page in the pre-text page count, but do not place a page number on it. The top margin on this page shall be 60mm. [Samples Included]

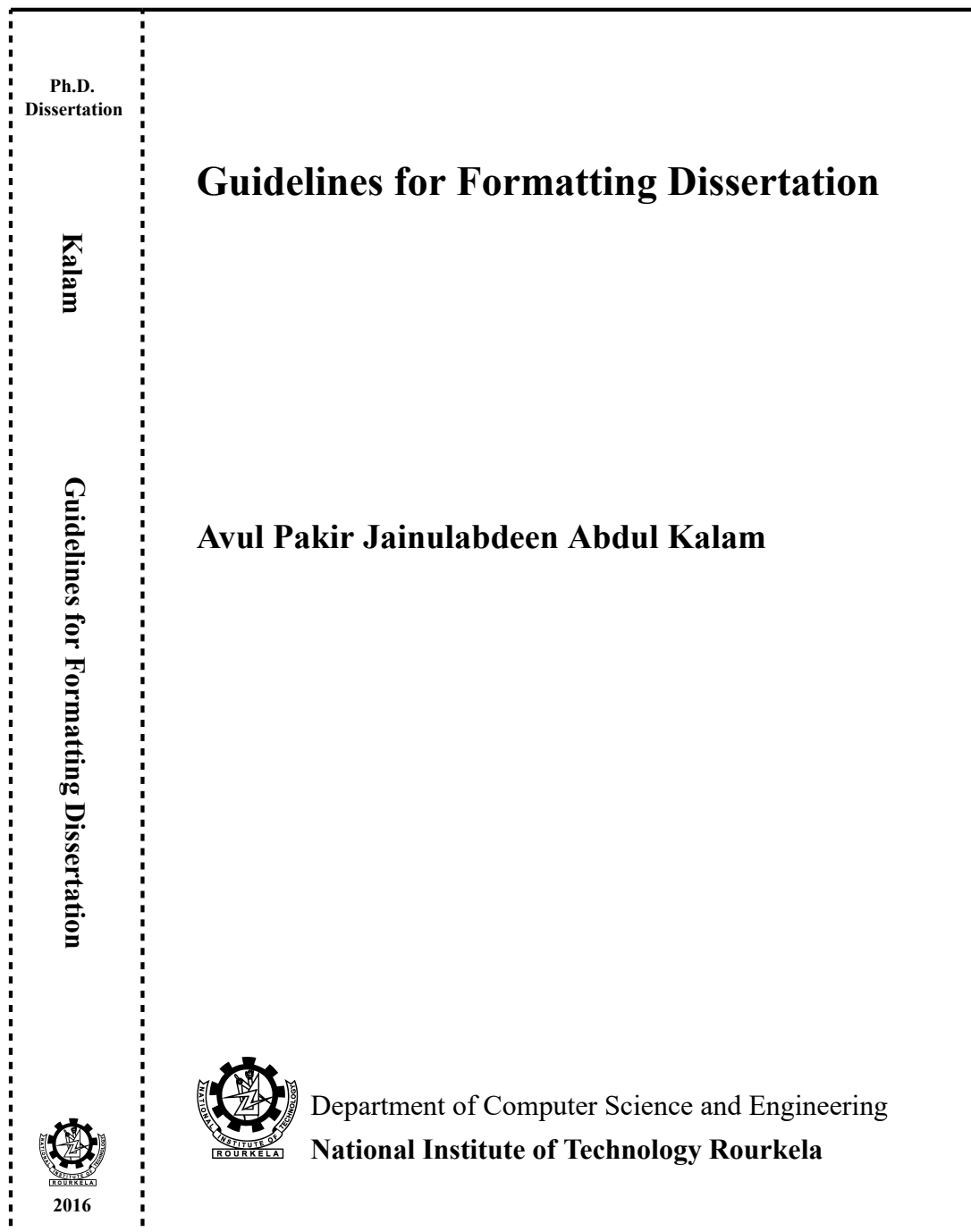


Figure 1.1: Cover page and spine.

v. **Dedication** [Optional]

This dedication page should be limited to one page. The author may choose his/her preferred font and size. Include this page in the pre-text page count, but do not place a page number on it. The top margin on this page shall be 60mm.

vi. **Declaration of Originality**

The student is expected to declare that the work and ideas in his/her dissertation are all his/her own and original. Include this page in the pre-text page count, but do not place a page number on it. A sample declaration is included. The top margin on this page shall be 60mm. [Sample Included]

vii. **Acknowledgment** [Optional]

Include this page in the pre-text page count, but do not place a page number on it. The top margin on this page shall be 60mm.

viii. **Abstract**

Abstract followed by three to seven keywords/phrases should be written in this section in no more than two pages. One may follow single line spacing in this section. Include this page in the pre-text page count, but do not place a page number on it. The top margin on this page shall be 60mm.

ix. **Contents**

Begin placing the page numbers at the bottom of this page, counting all preceding pages except the cover page. This counting should continue up to the page preceding the first page of the first chapter. Numbers should be in lower case Roman numerals. Page numbers are centered 15mm from the bottom of the page. The content pages should be generated automatically with the aid of software used for dissertation preparation. [Sample Included]

x. **List of Figures** [Optional]

This section should be generated automatically with the aid of software used for dissertation preparation. Continue the page numbering with lower case Roman numerals and place it 15mm from the bottom of the page. [Sample Included]

xi. **List of Tables** [Optional]

This section should be generated automatically with the aid of software used for dissertation preparation. Continue the page numbering with lower case Roman numerals and place it 15mm from the bottom of the page. [Sample Included]

xii. **List of Algorithms** [Optional]

This section should be generated automatically with the aid of software used for dissertation preparation. Continue the page numbering with lowercase Roman numerals. [Sample Included]

xiii. **List of Abbreviations** [Optional]

Continue the page numbering with lower case Roman numerals.

xiv. **List of Symbols** [Optional]

Continue the page numbering with lower case Roman numerals. Use separate lists for main, Greek symbols, subscripts, and superscripts.

xv. **Chapters**

All pages from the first page of the first chapter through the Vita should be numbered consecutively in Arabic numerals, beginning with numeral “1”. [Samples Included]

xvi. **Appendix** [Optional]

Continue page numbering with Arabic numerals.

xvii. **References**

References may be in one of the two commonly used styles: (a) numbered in sequence following the order of appearance, or (b) author and year of publication arranged alphabetically, depicting on the style used in the dominant journal in your field.

Please give names of ALL authors, surname first, title, name of journal, volume (bold), page numbers (start - end), and year of publication. Do not use “et al” in this section. You may use “*et al.*” while referring to article in the main text.

This section should be generated automatically with the aid of software used for dissertation preparation. There should be only one “Reference” section in a dissertation and should be placed after the Conclusion Chapter and before Appendices, if any. Continue page numbering with Arabic numerals. [Sample Included]

xviii. **Bibliography** [Optional]

A student may add a “Bibliography” section to present an exhaustive list of literature on the subject of the thesis. It is neither mandatory nor is encouraged. Articles mentioned here need not be cited in the main text. Documents given in “Reference” section may or may not be repeated in the bibliography.

xix. **Dissemination** [Optional]

There should be only one dissemination section in a dissertation and should be placed after the Reference section (or the Bibliography section, if there is one). Continue page numbering with Arabic numerals. [Sample Included]

xx. **Index** [Optional]

An index page comprises an alphabetical listing of some words or phrases along with the page numbers where they are discussed. Continue page numbering with Arabic numerals. [Sample Included]

Author's Official Name

Students must represent their full name as it is officially recorded at NIT Rourkela. The sequence to be followed is First Name, Middle Name, and Last Name. This official name must be used in the dissertation. This name will appear in the degree certificate. It is mandatory that this name should be same as that in Class X certificate. If there is a difference for any valid reason, please seek permission of Dean (Ac) before submitting dissertation.

1.2 Dissertation Layout

Students are advised to adhere to following points while writing their dissertation.

a. Institute logo

It is a matter of pride to print the Institute logo in the dissertation. The printed logo should be contained in a square of 25mm each side. Students are advised to use high resolution logo. A logo is provided in the dissertation writing template.

b. Paper

Essentially the same quality paper should be used throughout the dissertation. Use A4 size paper ($210mm \times 297mm$) of Executive Bond or comparable quality. Paper used in dissertation printing should weigh 80gsm. However, 70 or 75 gsm are also acceptable, but not thinner.

c. Margin

All pages of a dissertation should have a consistent margin of —

- 31mm on the left edge,
- 25mm each on the right, top, and bottom edges.

Page numbers must be placed at least 15mm from the bottom of the page. A pictorial representation of the page layout is shown in Figure 1.2.

d. Printing

The dissertation must be printed in black ink unless the content demands the use of colours. Print on a single side of the paper is advisable.

e. Spacing

The dissertation should be 1.5-spaced. However, Table of Contents, footnotes, graphs, tables, appendices, list of figures, list of tables, list of algorithms, references, bibliography, and index should be written in single space. Two consecutive paragraphs should be separated by double line spacing.

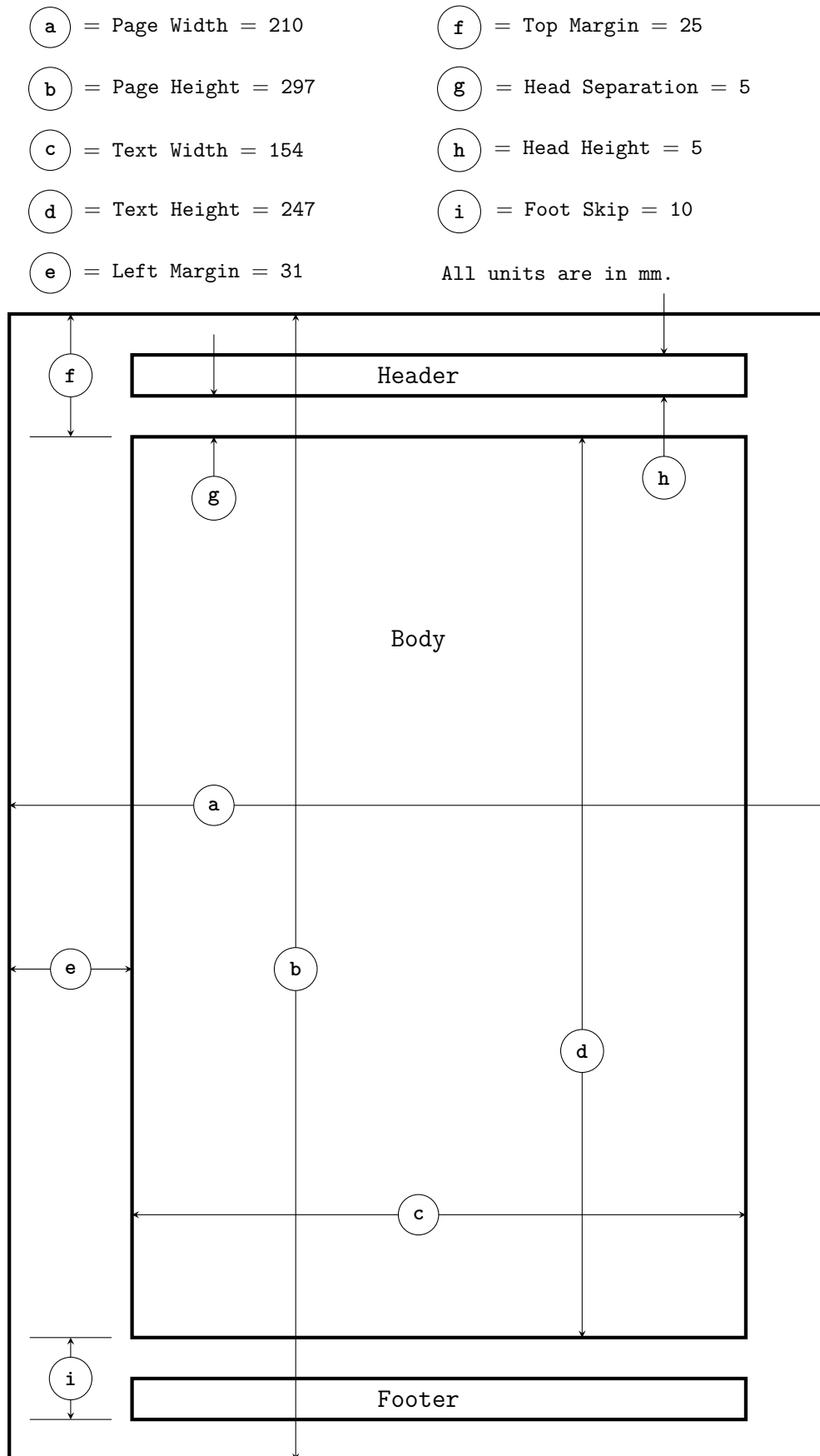


Figure 1.2: Page size and margin.

f. Font

The entire dissertation must be written using only a single font including all the texts inside graphs, figures, block diagrams, *etc.* While writing captions of tables and figures, the font size should be decreased by one point. Similarly, the font size of bibliography and index should also be lessened by a point. Students are advised to use the following in the body text —

serif fonts like Times New Roman (TNR) of size 12pt

or

sans-serif fonts like Arial of size 11pt.

Needless to say that the use of font should be uniform throughout. Headings, Titles *etc.* should use fonts as given below in Table 1.1.

Table 1.1: Font sizes to be used in the dissertation

Item	Arial	TNR	Justification
Main Text	11 normal	12 normal	Justified
Sub-sub Heading	11 bold	12 bold	Left
Sub Heading	13 bold	14 bold	Left
Heading [#]	16 bold	17 bold	Left
Chapter Title	22 bold	24 bold	Center
Chapter Number	16 bold	17 bold	Left

[#]Add serial number with one decimal place.

g. Table and Figure

All tables, figures, and other such illustrations referenced in the text should be numbered for unique identification. The number format should be $p.q$ with p signifying the chapter number where the illustration appears and q denoting the serial number of that illustration in the chapter p . The serial number should be set to 1 at the beginning of a new chapter. A table caption should be placed at the top of the table, and a figure caption should be placed at the bottom of the figure. The caption should follow the unique number $p.q$. The size of the font in the caption of tables and figures should be one less than the text font size.

h. References

“References” should be treated as the last chapter and placed at the end of the dissertation. It should not be numbered like other chapters. Texts within the references should have single spacing. The size of the font may be reduced by a point or two. Journal article (Shannon, 1948; Lowe, 2004), Patent (Edison, 1892; Droogenbroeck

& Barnich, 2010), book (Jain, 1989; Vapnik, 1995), conference article (Toyama et al., 1999; Lin & Canny, 1991), online resource (NASA, 1964; Fielding, 2007), Ph.D. dissertation (Sutherland, 1963; Dhawan, 1951) are usually referred in the text. Some samples of various bibliographic styles are included in this guideline for illustration. You are advised to follow one reference format of any dominant journal of your field.

1.3 Chapters

In the text of the dissertation, each chapter should begin on a fresh page. They should also be designated in the Table of Contents along with other major sections of each chapter. The page numbers listed on the Table of Contents must correlate with the beginning of each section or chapter. All texts should be written with 1.5-spacing. Each chapter should begin with a chapter number in Arabic numerals (font size: Times New Roman 17 points or Arial 16 points, Bold) followed by the chapter title in bold face of size 24 points in Times New Roman font or 22 points in Arial font.

The first level section should have number of format $a.b$, where the number a is an Arabic number denoting the chapter number and b is also an Arabic number starting from 1 and counting up for each section. For example 3.1, 4.2, or 1.5, *etc.* The section title should follow the section number. Both the title and number should be in the bold face of size 17 points in Times New Roman font or 16 points in Arial font.

The second level section should have number of format $a.b.c$, where c is an Arabic number. For example 3.1.1, 4.2.1, or 1.5.2 *etc.* The sub-section title in bold letters should follow the number in bold. The font size should be 14 points Times New Roman or 13 points Arial. Except when it is commonly followed in your field, it is suggested not to give serial number beyond $a.b$ stage, *i.e.* serializing like $a.b.c$ is discouraged.

The third level section should have no number. The sub-sub-section title should be in bold letters. The font size should be 12 points Times New Roman or 11 points Arial.

1.4 Compilation using L^AT_EX

The requisite templates to assist in formatting dissertation in L^AT_EX can be downloaded from <http://nitris.nitrkl.ac.in> (goto Academic -> Dissertation Template). The folder NITRdissertationTemplateV4_5 contains a number of file and sub folders as shown below in Figure 1.3. Fill in the details in FrontPages.tex. Compile your dissertation with the following commands to generate DissertationGuidelinesV4_5.pdf, or with your preferred integrated development environment (IDE).

```
>xelatex DissertationGuidelinesV4_5.tex
>bibtex DissertationGuidelinesV4_5
>xelatex DissertationGuidelinesV4_5.tex
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>xelatex DissertationGuidelinesV4_5.tex
```

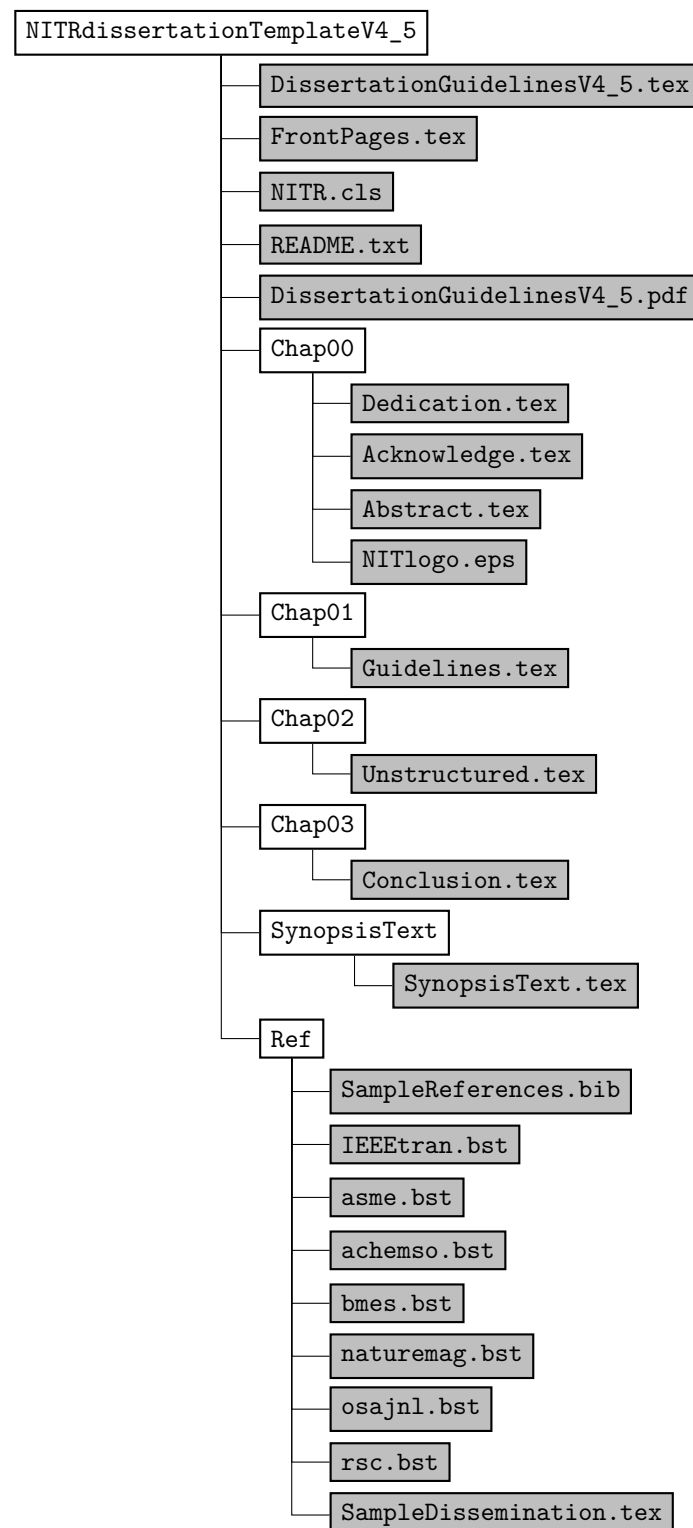


Figure 1.3: Files and folders in NITRdissertationTemplateV4_5

Chapter 2

Some Unstructured Advice on Dissertation Writing

Outside the domain of physical formatting and layout, this document does not intend to foray into the contents of the dissertation to be written. That would influence contents and stifle creativity. The following unstructured guidelines, however, may sometime prove useful to the students and their guides, who are looking for a good model.

2.1 Units

Appropriate use of style and convention for units are very much essential to ensure the scientific and technical communications not being inhibited by ambiguity. Authors may find the following points very useful.

- (a) Efforts should be made to use SI units where appropriate *e.g.* m, kg, s, K, A, V, Hz, N (Newton), J (Joule), W (Watt), Pa (Pascal), Tesla *etc.* It is, however, sometimes more appropriate to use common metric units such as km, mm, μm , nm, bar (pressure), mbar, MPa (Mega Pascal), $^{\circ}\text{C}$ *etc.* Non-SI metric units should be preferred when SI units lead to very high (*e.g.* > 1000) or very low (*e.g.* < 0.01) figures. Common units should be used when dealing with direct experimental data.
- (b) Non-metric units *e.g.* lb, ft, inch, $^{\circ}\text{F}$, esu, emu, psi should be religiously avoided. Often an instrument or a data source gives data in British units. Those information should be converted to corresponding SI (or non SI metric) units immediately on citation from the original text.
- (c) CGS units are sometimes appropriate depending on the field of work. But a conscious effort is to be made to translate them to corresponding SI units for example the unit g-mole or simply mole is common in chemistry; but chemical engineers should use kmol (for kilo-mole) and set Avogadro number to 6.023×10^{26} molecules per kmol instead of the figure 6.022×10^{23} molecules/gmole. Units ESU and EMU may be avoided in all fields.

- (d) Certain scientific quantities have traditionally been associated with corresponding units, *e.g.* cm^{-1} for wave number, μm , nm , \AA for wave length; do not convert them to SI. Between \AA and nm , we should prefer nm except for wavelengths below 1 nm or 10 \AA . Air conditioning temperatures should be expressed in $^{\circ}\text{C}$ and cryogenic temperature in Kelvin. Vacuum pressures should be recorded in millibar (mb) in preference to Torr.
- (e) Please note that all units start with lower case letters except those named after scientists. For example Watt (W), Joule (J), Kelvin (K), Ampere (A), Volt (V) start with upper case letters (W, J, K, A, V) while gramme (g), metre (m), second (s) start with lower case letters g, m, s.
- (f) kilo, mega, milli are represented by k, M, m respectively.

2.2 Significant figures

While reporting experimental or computational information, authors often use too short or excessively long numbers for the same quantity. Let us take an example. The area of a circle with radius of 1 cm may be reported as 3, 3.14, or 3.14159265 cm^2 . All are correct, but only one is appropriate, depending on the context.

The value of π is 3.1415926536... Depending on the control you or your instrument has set in the excel file, calculator or computer program you will get different results for the area of a circle for a given diameter. If your measured diameter is reported as 2.0 cm, it is certainly > 1.95 and < 2.05 cm. If it is reported as 2.000 cm, it is between 1.9995 and 2.0005 cm. The former measurement is from a very rough ruler, while the latter is from an extremely accurate instrument. The corresponding areas calculated should be reported as 3.14 and 3.1416 cm^2 respectively, bearing a little more precision than the original figures.

2.3 Grammar

Always ensure that your writing is based on correct grammar. Avoid very long sentences; but if you do use them, please mentally go through a process of analysis, ensuring proper division of the sentence to clauses and proper prepositions and conjunctions joining those clauses.

Articles (a, an, the) are frequently misused in Indian writing. The article “the” is usually over used. One simple test can correct many mistakes. We ask ourselves “Does the object in question appear first time in the text?” If the answer is “yes”, then use of “the” is most probably inappropriate. For example, the sentence “The bananas are yellow” is incorrect. But the sentences: “Barbie bought bananas from the market; the bananas were yellow” and “Ripe Bananas are yellow in eastern India” are correct.

2.4 Literature Review

The “Literature Review” is a very useful section of Indian theses. This section should cite most of the publications in the field including all related past work done. Several common mistakes found in recent theses from our country should be avoided.

Some theses reproduce, albeit using the author’s own language, a large amount of text book information. While for the sake of readability some basic ideas of the field may be articulated, it is certainly improper to reproduce large sections of text books. A reader is expected to have prior knowledge of the general field.

Authors sometimes summarise articles in serial order but neither bring out the link between one article and its following one, nor bring out the relation the article in question has with the main title of the thesis.

2.5 Materials and Methods

Experimental research in several research fields, particularly those dealing with material science, food technology, biotechnology *etc*, invariably contain a chapter on “Materials and Methods” which describe the instruments and chemicals used in the experiments, plus the processing techniques. This chapter is usually irrelevant in theses in electrical sciences and those relying on mathematical analysis. Use the practice followed in dissertations of your field.

2.6 Completeness and Transparency

There is often an erroneous impression among research students that it is his duty, privilege and right to protect the intellectual property which he has so painstakingly produced. He sometimes makes a conscious effort to suppress details of his discoveries, but more frequently he does not care to put in all relevant details of his analysis, construction or experiment in the thesis. A future reader trying to build up on the work of the author needs to reinvent all that the present author invented.

This goes against the philosophy of NIT Rourkela and of the scholastic spirit around the world. A thesis from NIT Rourkela must contain all analyses and all steps of experimentation that have gone into the work so that an intelligent researcher anywhere in the world would find it useful to further his work.

Chapter 3

Conclusion

The conclusion is one of the most important chapters of the dissertation and often it is one of the most badly written chapters.

The student is expected to make a clear and concise statement of the original contributions made in the dissertation. The links between the key ideas spread across the chapters should be briefed in this chapter. Leave a positive impression with the examiner. One must remember not to claim those findings that have neither been proven nor corroborated in the dissertation.

Scope for Further Research

This is not the end of the road. Narrate the way the research can be furthered.

References

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⁰This reference format follows ASME style. You are advised to follow one reference format of any dominant journal of your field.

Dissemination

Internationally indexed journals (*Web of Science, SCI, Scopus, etc.*)¹

1. something
2. something

Other journals and Book chapters ¹

1. something
2. something

Conferences ¹

1. something
2. something

Article under preparation ²

1. something
2. something

¹Articles already published, in press, or formally accepted for publication.

²Articles under review, communicated, or to be communicated.

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