Thesis

A Thesis
Presented to
The Division of Mathematics and Natural Sciences
Reed College

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Arts

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I want to thank a few people.

Preface

This is an example of a thesis setup to use the reed thesis document class.

List of Abbreviations

You can always change the way your abbreviations are formatted. Play around with it yourself, use tables, or come to CUS if you'd like to change the way it looks. You can also completely remove this chapter if you have no need for a list of abbreviations. Here is an example of what this could look like:

DP Differential Privacy

Table of Contents

List of Tables

List of Figures

Abstract

The preface pretty much says it all.

Dedication

You can have a dedication here if you wish.

Introduction

Welcome to the LaTeX thesis template. If you've never used TeX or LaTeX before, you'll have an initial learning period to go through, but the results of a nicely formatted thesis are worth it for more than the aesthetic benefit: markup like LaTeX is more consistent than the output of a word processor, much less prone to corruption or crashing and the resulting file is smaller than a Word file. While you may have never had problems using Word in the past, your thesis is going to be about twice as large and complex as anything you've written before, taxing Word's capabilities. If you're still on the fence about using LaTeX, read the Introduction to LaTeX on the CUS site as well as skim the following template and give it a few weeks. Pretty soon all the markup gibberish will become second nature.

0.1 Why use it?

LaTeX does a great job of formatting tables and paragraphs. Its line-breaking algorithm was the subject of a PhD. thesis. It does a fine job of automatically inserting ligatures, and to top it all off it is the only way to typeset good-looking mathematics.

0.2 Who should use it?

Anyone who needs to use math, tables, a lot of figures, complex cross-references, IPA or who just cares about the final appearance of their document should use LaTeX. At Reed, math majors are required to use it, most physics majors will want to use it, and many other science majors may want it also.

Chapter 1

Background

1.1 Differential Privacy

This section is an adaptation of Dork and Roth's The Algorithmic Foundations of Differential Privacy.

1.1.1 What is Differential Privacy

Differential Privacy is a definition for privately sharing information from a database without compromising an individual's privacy. It ensures that neither the participation of the individual in the database nor any of their data will be disclosed when using a differentially private process.

Differential privacy ensures protection against any kind of attack, removing the need for attack modelling, it prevents linkage attacks as its definition doesn't depend on the availability of external databases, it allows the quantification of the privacy loss allowing comparison between different techniques, it ensures the quantification of the privacy loss over when composing multiple processes, it provides group privacy by accounting for privacy loss created by linked individuals, and post processing cannot increase the privacy loss of a given process by computing its output with another function.

It is important to note that this definition applies to a process over a database, not to a database itself, and ensures that if the process is differentially private, then removing one individual from the input database over which the process is applied, will yield a measurable similar output as if the individual wasn't removed. It is also important to note that Differential Privacy is not a technique, but a definition, and are the techniques the ones that adhere to the definition.

Differential Privacy is usually achieved by adding noise to the data. That noise is obtained usually from a probability distribution, being Laplace and Gauss distributions the most common. Adding noise happens within the process or the algorithm that is differentially private.

The amount of noise added to the data depends on different parameters, being them the type of algorithm, whether the model is local or global, the data itself, and whether the queries are online or offline.

1.1.2 Differential Privacy Definitions

As mentioned before, differentially private processes adhere to a Differential Privacy definition. The two main definitions are ε-Differential Privacy and (ε, δ)-Differential Privacy.

ε-Differential Privacy

ε-DP ensures that for every run of the differentially private algorithm, the output is almost equally likely to be observed on every neighboring database simultaneously. ε-Differential Privacy ensures that a process that adheres to this definition, will yield basically the same output if you change the data of one individual.

A randomized algorithm $\mathcal{M}$ with domain $\mathbf{N}^{|X|}$ is ε-differentially private if for all $\mathcal{S} \subseteq Range(\mathcal{M})$ and for all $x, y \in \mathbf{N}^{|X|}$ such that $\| x, y \|_1 \leq 1$:

$$Pr[\mathcal{M}(x) \in \mathcal{S}] \leq exp(\varepsilon) Pr[\mathcal{M}(y) \in \mathcal{S}]$$

(ε, δ)-Differential Privacy

(ε, δ)-DP ensures that in neighboring databases it is extremely unlikely that the output will be much more or less likely in the database with the individual than in the one without them.

A randomized algorithm $\mathcal{M}$ with domain $\mathbf{N}^{|X|}$ is (ε, δ)-differentially private if for all $\mathcal{S} \subseteq Range(\mathcal{M})$ and for all $x, y \in \mathbf{N}^{|X|}$ such that $\| x, y \|_1 \leq 1$:

$$Pr[\mathcal{M}(x) \in \mathcal{S}] \leq exp(\varepsilon) Pr[\mathcal{M}(y) \in \mathcal{S}] + \delta$$

δ captures the probability that things go terribly wrong, specifically it captures the probability that the absolute value of the privacy loss is bounded by ε.

1.1.3 Privacy Loss

One of the novel characteristics of differential privacy is that it is possible to measure the privacy loss incurred by a differential privacy algorithm.

Given an output $\xi \sim \mathcal{M}(x)$, it might be possible for that output to be produced with higher probability on a database x than on a database y or vice-versa. That difference is captured by the privacy loss:

$$\mathcal{L}^{(\xi)}_{\mathcal{M}(x)||\mathcal{M}(y)} = ln(\frac{Pr[\mathcal{M}(x) = \xi]}{Pr[\mathcal{M}(y) = \xi]})$$

1.1.4 Local Differential Privacy model

Local Differential Privacy model (or fully distributed model) is the variant of Differential Privacy in which the source of each data point are the ones that apply a differentially private process, rather than sending their data points to a centralized database and then the owner of the database applying the differentially private process to it. LDP allows for the data sources to keep full ownership of non-DP data, but leads to having greater noise than when using a Global Differential Privacy model. Local Differential Privacy has gained adoption in ultra large technology companies that are able to offset the increased noise with billions of users' data in use cases where data accuracy is not fundamental.

1.1.5 Additive Noise Mechanisms

The two most relevant methods to add noise to data are the Laplace Mechanism, and the Gaussian Mechanism, taking the name from the distributions they originate from. In the case of the paper addressed by this thesis, the Gaussian mechanism is used, as it leads to less noise in data with multiple categories.

Sensitivity

The sensitivity of a function is how much the output of the function changes when a single data point is added. It allows for determining the maximum amount of noise necessary to hide the participation of a single individual.

$$\Delta f = \max ||f(x) - f(y)||$$

where x and y are databases that differ by one datapoint.

Calculating the sensitivity is straightforward when the database only has one category, but when there is more than one category, and the response from the algorithm is a vector, calculating the sensitivity, as it depends on a distance calculation, can be done in different ways. In the case of the Laplace Mechanism, the ℓ_1-norm (Mannhattan distance) is used, but in the case of the Gaussian Mechanism, the ℓ_2-norm (Euclidean distance) is used.

Laplace Mechanism

$$\mathcal{M}_{\text{Lap}}(x, f, \epsilon) = f(x) + \text{Lap}\left(\mu = 0, b = \frac{\Delta f}{\epsilon}\right)$$

The Laplace Mechanism preserves (ϵ, 0)-differential privacy.

Proof. Let $x \in \mathbb{N}^{|\mathcal{X}|}$ and $y \in \mathbb{N}^{|\mathcal{X}|}$ be such that $||x - y||_1 \leq 1$, and let $f(\cdot)$ be some function $f : \mathbb{N}^{|\mathcal{X}|} \to \mathbb{R}^k$. Let p_x denote the probability density function of $\mathcal{M}_L(x, f, \epsilon)$, and let p_y denote the probability density function $\mathcal{M}_L(x, f, \epsilon)$. We compare the two at some arbitrary point $z \in \mathbb{R}^k$

$$\begin{aligned}
\frac{p_x(z)}{p_y(z)} &= \prod_{i=1}^{k} \left(\frac{\exp(-\frac{\varepsilon |f(x)_i - z_i|}{\Delta f})}{\exp(-\frac{\varepsilon |f(y)_i - z_i|}{\Delta f})} \right) \\
&= \prod_{i=1}^{k} \exp\left(\frac{\varepsilon(|f(y)_i - z_i| - f(x)_i - z_i|)}{\Delta f} \right) \\
&\leq \prod_{i=1}^{k} \exp\left(\frac{\varepsilon |f(x)_i - f(y)_i|}{\Delta f} \right) \\
&= \exp\left(\frac{\varepsilon \cdot ||f(x) - f(y)||_1}{\Delta f} \right) \\
&\leq \exp(\varepsilon),
\end{aligned}$$

where the first inequality follows from the triangle inequality, and the last follows from the definition of sensitivity and the fact that $||x - y||_1 \leq 1$. That $\frac{p_x(x)}{p_y(z)} \geq \exp(-\varepsilon)$ follows by symmetry.

Example. Consider a counting query that asks for the amount of datapoints in a database that satisfy a condition C. The sensitivity of this function will be 1, as it is how much the output will change with the adddition of a new datapoint. It follows that ε-differential privacy if noise is drawn from Laplace($1/\varepsilon$).

Guassian Mechanism

$$\mathcal{M}_{\text{Gauss}}(x, y, \epsilon, \delta) = f(x) + \mathcal{N}^d \left(\mu = 0, \sigma^2 = \frac{2ln(1.25/\epsilon)\dot{(}\Delta f)^2}{\epsilon^2} \right)$$

Using the Gaussian Mechanism is useful when a single datapoint can affect more than one statistic and the differentially private algorithm returns more than one of those statistics, and we don't need $\delta = 0$.

This is due to the way sensitivity is calculated in the Laplace and Gaussian cases. As mentioned in the sensitivity subsection, the Laplace Mechanism uses ℓ_1-norm, and the Gaussian Mechanism uses the ℓ_2-norm, meaning that when a single datapoint affects k different statistics, the Laplace Mechanism scales the noise by k, while the Gaussian Mechanism scales the noise by $\sqrt{k}$.

1.2 Linear Queries

Chapter 2

The First

This is the first page of the first chapter. You may delete the contents of this chapter so you can add your own text; it's just here to show you some examples.

2.1 References, Labels, Custom Commands and Footnotes

It is easy to refer to anything within your document using the `label` and `ref` tags. Labels must be unique and shouldn't use any odd characters; generally sticking to letters and numbers (no spaces) should be fine. Put the label on whatever you want to refer to, and put the reference where you want the reference. LaTeX will keep track of the chapter, section, and figure or table numbers for you.

2.1.1 References and Labels

Sometimes you'd like to refer to a table or figure, e.g. you can see in Figure 4.2 that you can rotate figures . Start by labeling your figure or table with the label command (`\label{labelvariable}`) below the caption (see the chapter on graphics and tables for examples). Then when you would like to refer to the table or figure, use the ref command (`\ref{labelvariable}`). Make sure your label variables are unique; you can't have two elements named "default." Also, since the reference command only puts the figure or table number, you will have to put "Table" or "Figure" as appropriate, as seen in the following examples:

As I showed in Table 4.1 many factors can be assumed to follow from inheritance. Also see the Figure 4.1 for an illustration.

2.1.2 Custom Commands

Are you sick of writing the same complex equation or phrase over and over?

The custom commands should be placed in the preamble, or at least prior to the first usage of the command. The structure of the `\newcommand` consists of the name of the new command in curly braces, the number of arguments to be made in square brackets and then, inside a new set of curly braces, the command(s) that make up the new command. The whole thing is sandwiched inside a larger set of curly braces.

In other words, if you want to make a shorthand for H_2SO_4, which doesn't include an argument, you would write: `\newcommand{\hydro}{H$_2$SO$_4$}` and then when you needed to use the command you would type `\hydro`. (sans verb and the equals sign brackets, if you're looking at the .tex version). For example: H_2SO_4

2.1.3 Footnotes and Endnotes

You might want to footnote something.[1] Be sure to leave no spaces between the word immediately preceding the footnote command and the command itself. The footnote will be in a smaller font and placed appropriately. Endnotes work in much the same way. More information can be found about both on the CUS site.

2.2 Bibliographies

Of course you will need to cite things, and you will probably accumulate an armful of sources. This is why BibTeX was created. For more information about BibTeX and bibliographies, see our CUS site (`web.reed.edu/cis/help/latex/index.html`)[2]. There are three pages on this topic: *bibtex* (which talks about using BibTeX, at `/latex/bibtex.html`), *bibtexstyles* (about how to find and use the bibliography style that best suits your needs, at `/latex/bibtexstyles.html`) and *bibman* (which covers how to make and maintain a bibliography by hand, without BibTeX, at at `/latex/bibman.html`). The last page will not be useful unless you have only a few sources. There used to be APA stuff here, but we don't need it since I've fixed this with my apa-good natbib style file.

2.2.1 Tips for Bibliographies

1. Like with thesis formatting, the sooner you start compiling your bibliography for something as large as thesis, the better. Typing in source after source is mind-numbing enough; do you really want to do it for hours on end in late April? Think of it as procrastination.

2. The cite key (a citation's label) needs to be unique from the other entries.

3. When you have more than one author or editor, you need to separate each author's name by the word "and" e.g.
   `Author = {Noble, Sam and Youngberg, Jessica},`.

4. Bibliographies made using BibTeX (whether manually or using a manager) accept LaTeX markup, so you can italicize and add symbols as necessary.

[1] footnote text

[2] Reed College (2007)

5. To force capitalization in an article title or where all lowercase is generally used, bracket the capital letter in curly braces.

6. You can add a Reed Thesis citation[3] option. The best way to do this is to use the phdthesis type of citation, and use the optional "type" field to enter "Reed thesis" or "Undergraduate thesis". Here's a test of Chicago, showing the second cite in a row[4] being different. Also the second time not in a row[5] should be different. Of course in other styles they'll all look the same.

2.3 Anything else?

If you'd like to see examples of other things in this template, please contact CUS (email cus@reed.edu) with your suggestions. We love to see people using LaTeX for their theses, and are happy to help.

[3]Noble (2002)
[4]Noble (2002)
[5]Reed College (2007)

Chapter 3

Mathematics and Science

3.1 Math

TEX is the best way to typeset mathematics. Donald Knuth designed TEX when he got frustrated at how long it was taking the typesetters to finish his book, which contained a lot of mathematics.

If you are doing a thesis that will involve lots of math, you will want to read the following section which has been commented out. If you're not going to use math, skip over this next big red section. (It's red in the .tex file but does not show up in the .pdf.)

3.2 Chemistry 101: Symbols

Chemical formulas will look best if they are not italicized. Get around math mode's automatic italicizing by using the argument `$\mathrm{formula here}$`, with your formula inside the curly brackets.

So, $\mathrm{Fe_2^{2+}Cr_2O_4}$ is written `$\mathrm{Fe_2^{2+}Cr_2O_4}$`
Exponent or Superscript: $\mathrm{O^-}$
Subscript: $\mathrm{CH_4}$

To stack numbers or letters as in $\mathrm{Fe_2^{2+}}$, the subscript is defined first, and then the superscript is defined.
Angstrom: Å
Bullet: $\mathrm{CuCl \bullet 7H_2O}$
Double Dagger: ‡
Delta: Δ
Reaction Arrows: $\longrightarrow$ or $\xrightarrow{solution}$
Resonance Arrows: $\leftrightarrow$
Reversible Reaction Arrows: $\rightleftharpoons$ or $\xrightleftharpoons{solution}$ (the latter requires the chemarr package)

3.2.1 Typesetting reactions

You may wish to put your reaction in a figure environment, which means that LaTeX will place the reaction where it fits and you can have a figure legend if desired:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Figure 3.1: Combustion of glucose

3.2.2 Other examples of reactions

$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$
$MeCH_2Br + Mg \xrightarrow[below]{above} MeCH_2 \bullet Mg \bullet Br$

3.3 Physics

Many of the symbols you will need can be found on the math page (`http://web.reed.edu/cis/help/latex/math.html`) and the Comprehensive LaTeX Symbol Guide (enclosed in this template download). You may wish to create custom commands for commonly used symbols, phrases or equations, as described in Chapter 2.1.2.

3.4 Biology

You will probably find the resources at `http://www.lecb.ncifcrf.gov/~toms/latex.html` helpful, particularly the links to bsts for various journals. You may also be interested in TeXShade for nucleotide typesetting (`http://homepages.uni-tuebingen.de/beitz/txe.html`). Be sure to read the proceeding chapter on graphics and tables, and remember that the thesis template has versions of Ecology and Science bsts which support webpage citation formats.

Chapter 4

Tables and Graphics

4.1 Tables

The following section contains examples of tables, most of which have been commented out for brevity. (They will show up in the .tex document in red, but not at all in the .pdf). For more help in constructing a table (or anything else in this document), please see the LaTeX pages on the CUS site.

Table 4.1: Correlation of Inheritance Factors between Parents and Child

Factors	Correlation between Parents & Child	Inherited
Education	-0.49	Yes
Socio-Economic Status	0.28	Slight
Income	0.08	No
Family Size	0.19	Slight
Occupational Prestige	0.21	Slight

If you want to make a table that is longer than a page, you will want to use the longtable environment. Uncomment the table below to see an example, or see our online documentation.

Table 4.2: Chromium Hexacarbonyl Data Collected in 1998–1999

Chromium Hexacarbonyl			
State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
$z^7P^\circ_4$	266 nm	Argon	1.5
$z^7P^\circ_2$	355 nm	Argon	0.57
$y^7P^\circ_3$	266 nm	Argon	1
$y^7P^\circ_3$	355 nm	Argon	0.14
$y^7P^\circ_2$	355 nm	Argon	0.14
$z^5P^\circ_3$	266 nm	Argon	1.2
$z^5P^\circ_3$	355 nm	Argon	0.04
$z^5P^\circ_3$	355 nm	Helium	0.02
$z^5P^\circ_2$	355 nm	Argon	0.07
$z^5P^\circ_1$	355 nm	Argon	0.05
$y^5P^\circ_3$	355 nm	Argon	0.05, 0.4
$y^5P^\circ_3$	355 nm	Helium	0.25
$z^5F^\circ_4$	266 nm	Argon	1.4
$z^5F^\circ_4$	355 nm	Argon	0.29
$z^5F^\circ_4$	355 nm	Helium	1.02
$z^5D^\circ_4$	355 nm	Argon	0.3
$z^5D^\circ_4$	355 nm	Helium	0.65
$y^5H^\circ_7$	266 nm	Argon	0.17
$y^5H^\circ_7$	355 nm	Argon	0.13
$y^5H^\circ_7$	355 nm	Helium	0.11
a^5D_3	266 nm	Argon	0.71
a^5D_2	266 nm	Argon	0.77
a^5D_2	355 nm	Argon	0.63
a^3D_3	355 nm	Argon	0.05
a^5S_2	266 nm	Argon	2
a^5S_2	355 nm	Argon	1.5
a^5G_6	355 nm	Argon	0.91
a^3G_4	355 nm	Argon	0.08
e^7D_5	355 nm	Helium	3.5
e^7D_3	355 nm	Helium	3
f^7D_5	355 nm	Helium	0.25
f^7D_5	355 nm	Argon	0.25
f^7D_4	355 nm	Argon	0.2
f^7D_4	355 nm	Helium	0.3
Propyl-ACT			

State	Laser wavelength	Buffer gas	Ratio of $\frac{\text{Intensity at vapor pressure}}{\text{Intensity at 240 Torr}}$
$z^7P_4^\circ$	355 nm	Argon	1.5
$z^7P_3^\circ$	355 nm	Argon	1.5
$z^7P_2^\circ$	355 nm	Argon	1.25
$z^7F_5^\circ$	355 nm	Argon	2.85
$y^7P_4^\circ$	355 nm	Argon	0.07
$y^7P_3^\circ$	355 nm	Argon	0.06
$z^5P_3^\circ$	355 nm	Argon	0.12
$z^5P_2^\circ$	355 nm	Argon	0.13
$z^5P_1^\circ$	355 nm	Argon	0.14
Methyl-ACT			
$z^7P_4^\circ$	355 nm	Argon	1.6, 2.5
$z^7P_4^\circ$	355 nm	Helium	3
$z^7P_4^\circ$	266 nm	Argon	1.33
$z^7P_3^\circ$	355 nm	Argon	1.5
$z^7P_2^\circ$	355 nm	Argon	1.25, 1.3
$z^7F_5^\circ$	355 nm	Argon	3
$y^7P_4^\circ$	355 nm	Argon	0.07, 0.08
$y^7P_4^\circ$	355 nm	Helium	0.2
$y^7P_3^\circ$	266 nm	Argon	1.22
$y^7P_3^\circ$	355 nm	Argon	0.08
$y^7P_2^\circ$	355 nm	Argon	0.1
$z^5P_3^\circ$	266 nm	Argon	0.67
$z^5P_3^\circ$	355 nm	Argon	0.08, 0.17
$z^5P_3^\circ$	355 nm	Helium	0.12
$z^5P_2^\circ$	355 nm	Argon	0.13
$z^5P_1^\circ$	355 nm	Argon	0.09
$y^5H_7^\circ$	355 nm	Argon	0.06, 0.05
a^5D_3	266 nm	Argon	2.5
a^5D_2	266 nm	Argon	1.9
a^5D_2	355 nm	Argon	1.17
a^5S_2	266 nm	Argon	2.3
a^5S_2	355 nm	Argon	1.11
a^5G_6	355 nm	Argon	1.6
e^7D_5	355 nm	Argon	1

4.2 Figures

If your thesis has a lot of figures, LaTeX might behave better for you than that other word processor. One thing that may be annoying is the way it handles "floats" like tables and figures. LaTeX will try to find the best place to put your object based on the text around it and until you're really, truly done writing you should just leave it where it lies. There are some optional arguments to the figure and table environments to specify where you want it to appear; see the comments in the first figure.

If you need a graphic or tabular material to be part of the text, you can just put it inline. If you need it to appear in the list of figures or tables, it should be placed in the floating environment.

To get a figure from StatView, JMP, SPSS or other statistics program into a figure, you can print to pdf or save the image as a jpg or png. Precisely how you will do this depends on the program: you may need to copy-paste figures into Photoshop or other graphic program, then save in the appropriate format.

Below we have put a few examples of figures. For more help using graphics and the float environment, see our online documentation.

And this is how you add a figure with a graphic:

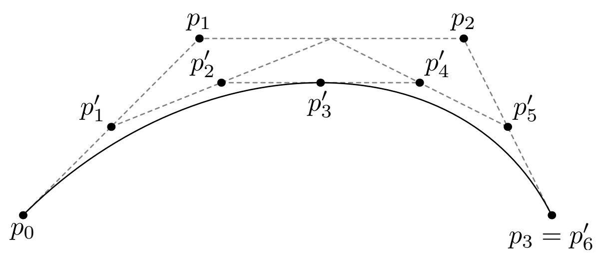

Figure 4.1: A Figure

4.3 More Figure Stuff

You can also scale and rotate figures.

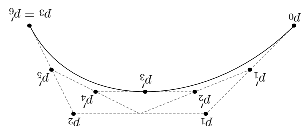

Figure 4.2: A Smaller Figure, Flipped Upside Down

4.4 Even More Figure Stuff

With some clever work you can crop a figure, which is handy if (for instance) your EPS or PDF is a little graphic on a whole sheet of paper. The viewport arguments are the lower-left and upper-right coordinates for the area you want to crop.

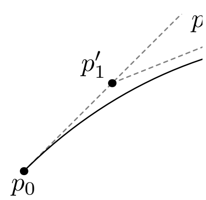

Figure 4.3: A Cropped Figure

4.4.1 Common Modifications

The following figure features the more popular changes thesis students want to their figures. This information is also on the web at `web.reed.edu/cis/help/latex/graphics.html`.

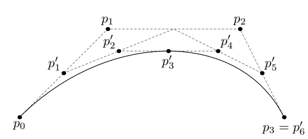

Figure 4.4: Subdivision of arc segments. You can see that $p_3 = p'_6$.

Conclusion

Here's a conclusion, demonstrating the use of all that manual incrementing and table of contents adding that has to happen if you use the starred form of the chapter command. The deal is, the chapter command in LaTeX does a lot of things: it increments the chapter counter, it resets the section counter to zero, it puts the name of the chapter into the table of contents and the running headers, and probably some other stuff.

So, if you remove all that stuff because you don't like it to say "Chapter 4: Conclusion", then you have to manually add all the things LaTeX would normally do for you. Maybe someday we'll write a new chapter macro that doesn't add "Chapter X" to the beginning of every chapter title.

4.1 More info

And here's some other random info: the first paragraph after a chapter title or section head *shouldn't be* indented, because indents are to tell the reader that you're starting a new paragraph. Since that's obvious after a chapter or section title, proper typesetting doesn't add an indent there.

Appendix A

The First Appendix

Appendix B

The Second Appendix, for Fun

References

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