TÉCNICO LISBOA

[MSc Thesis Title]

[MSc Thesis Subtitle]

[Author's Full Name]

Thesis to obtain the Master of Science Degree in

[Degree Name]

Supervisors: [Supervisor's Full Name]
[Co-Supervisor's Full Name]

Examination Committee

Chairperson: [Chairperson's Full Name, as in Fénix]
Supervisor: [Supervisor's Full Name, as in Fénix]
Member of the Committee: [Committee Member's Full Name, as in Fénix]
[Committee Member's Full Name, as in Fénix]

[Month & Year]

You can use this space for a dedication

Or maybe a quote

Acknowledgements

As a point of orthography, "Acknowledgments" is the American spelling, and "Acknowledgements" the other spelling. You can change the \acknowledgments command in `thesis_preamble.tex`.

This template is based on the one built by Diogo Ribeiro and Pedro Cosme. André Cordeiro later fixed some glitches with the formatting.

Resumo

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Palavras-chave: Palavra-Chave 1; Palavra-Chave 2; Palavra-Chave 3;
Palavra-Chave 4; Palavra-Chave 5; Palavra-Chave 6

Abstract

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Keywords: Keyword 1; Keyword 2; Keyword 3; Keyword 4; Keyword 5; Keyword 6

Table of Contents

List of Tables

List of Figures

List of Symbols

Greek symbols

γ^μ Dirac matrix.

μ, ν, σ Spacetime indices.

$\varepsilon_\mu(p)$ Polarisation for gluons (incoming).

$\varepsilon_\mu(p)^*$ Polarisation for gluons (outgoing).

Roman symbols

$\mathscr{L}$ Lagrangian, or lagrangian density.

$\bar{u}(p)$ Spinor for fermions (outgoing).

$\bar{v}(p)$ Spinor for antifermions (incoming).

$u(p)$ Spinor for fermions (incoming).

$v(p)$ Spinor for antifermions (outgoing).

f^{abc} SU(N) structure functions.

T^a_{ij} SU(N) generator.

Subscripts

i, j, k Colour indices pertaining to the fundamental representation.

Superscripts

a, b, c Colour indices pertaining to the adjoint representation.

Other

∂_μ Partial derivative.

List of Abbreviations

AA nucleus-nucleus.

C/A Cambridge-Aachen.

CERN Conseil Européen pour la Recherche Nucléaire.

DGLAP Dokshitzer-Gribov-Lipatov-Altarelli-Parisi.

DLA Double Logarithmic Approximation.

FF Fragmentation Function.

HIC Heavy Ion Collision.

IQR Interquartile Range.

LHC Large Hadron Collider.

LLA Leading Logarithmic Approximation.

PDF Parton Distribution Function.

pp proton-proton.

pQCD Perturbative Quantum Chromodynamics.

QCD Quantum Chromodynamics.

QGP Quark-Gluon Plasma.

RHIC Relativistic Heavy Ion Collider.

Chapter 1

A Tour of the Template

This template is intended for use in Master's Theses at *Instituto Superior Técnico*, and is in accordance with the guidelines in the *Guia de Preparação da Dissertação 2015/16* (the most recent at time of writing). The current version is an adaptation of the templates developed and used by former MEFT students Pedro Cosme, Diogo Ribeiro, and André Cordeiro. André Cordeiro is responsible for the most recent changes to this version, especially with regards to the *List of Symbols*, the disposition of the "Sample Chapter" 2, and the configuration of the *Bibliography* (mainly the hyperlinks).

The remainder of this chapter contains a description of the project structure, along with some noteworthy commands that may be edited to taste. Nonetheless, the user should read the configuration files (or `Ctrl + F` through them), in order to fine tune this template.

1.1 Project structure

This thesis template is separated into several files for easy editing. The `main.tex` file serves as the base document from where all other files are inserted. In the main folder you can find 4 separate folders.

1.1.1 The `/config` folder

The `/config` folder contains two configuration files that should be edited with care:

- `thesis-preamble.tex` – Contains all packages required by the template as well as some useful ones for writing mathematical expressions, defining tables and including figures. It also contains the commands for setting up the thesis geometry and looks.

  - `\usepackage[labelfont=bf,font=small]{caption}` is used to set the "**Figure X.Y:**" to be in boldface. Same is done for subcaptions.

  - `\usepackage{cmbright}` and `\newcommand{\fontnamestring}{cmbr}` are done to set the font to Computer Modern Bright for both math mode and normal text.

- \hypersetup is called to set the options for hyperlinks inside the document (this includes e.g. the colour of references).

- \captionsetup{width=.85\textwidth} is called to define the width of captions.

- The openright class option makes sure that the chapters start on odd-numbered pages. The emptypage package ensures that the blank pages are not numbered. Some blank pages had to be manually included to make sure the first chapter starts on the right hand side of the spread (on the front page of each leaf).

- my-commands.tex – Contains user defined commands. I have some packages used for this template, as well as some commands pertaining to typesetting subscripts and superscripts.

- biblio-setup.tex – Defines the bibliography style as it appears on this .pdf.

  - \usepackage[<options>]{biblatex} is called to configure the bibliography. Check these options carefully, reading the comments to each portion of the code.

1.1.2 The /input folder

After the document is configured, the actual writing can begin. In the /input folder you will find several folders with several documents inside:

- /01-Cover-Page – A cover according to *IST* regulations. The names of the author, supervisors, and committee members must be added, as well as the name of the degree. You can also choose a cover image.

- /02-Front-Matter – The Front Matter of a thesis is composed of the *Dedication*, *Acknowledgements*, *Abstract* and *Resumo* files. Although these are included in the *Table of Contents*, they can be removed by commenting out the \addcontentsline{toc}{chapter}{<Name>} line in the respective files. They can also be formatted as sections by changing \chapter*{<Name>} to \section*{<Name>}.

  - In the *Dedication* file you may dedicate the thesis to someone or write a quote.

  - The *Acknowledgements* page allow you to acknowledge a funding grant, some organisation, or people whose importance to you and your work should be mentioned.

  - The *Abstract* and *Resumo* pages should be essentially the same (albeit in different languages) and should contain a brief summary of your work. Since the character limit is identical for both languages, it may be useful to have slightly different texts in the *Abstract* and *Resumo* chapters.

- /03-Glossary-and-Nomenclature – The *List of Abbreviations*/*Glossary* pages should contain important acronyms that you use throughout the thesis. You may also include mathematical symbols to form a *List of Symbols*/*Nomenclature* page, although this is not mandatory. Special care must be taken when compiling these sections, as described below.

- `/04-Chapters` – Most writing happens inside this folder. Here you should create a separate file for each chapter. Chapter files may start in the following manner

```
\chapter{Chapter name}
\label{chapter:chapter_name}
```

  as to allow you to refer to the chapter further down the writing.

- `/05-Appendix` – The appendix folder works in the same fashion as the chapter folder. Separate files for each appendix should be created and edited.

1.1.3 The `/figures` folder

All graphics to be included in the main document should be placed inside this folder. We recommend separating the files to be included in separate folders according to the chapter they are to be placed in. The second chapter of this template contains some examples of how to incorporate the graphics in the main text.

1.1.4 The `/bib` folder

Finally, the bibliography is handled by the `/bib` folder. Inside you will find the file `msc-bibliography.bib` where all the references should be placed. The bibliography entries may have a format similar to:

```
@article{Einstein:1905,
author = "Einstein, Albert",
title = "{On the electrodynamics of moving bodies}",
doi = "10.1002/andp.200590006",
journal = "Annalen Phys.",
volume = "17",
pages = "891--921",
year = "1905"
}
```

and be cited with the `\cite` command as [1]. To cite multiple sources at once, do [2–4]. To specify a page in a source, one can say [5, p. 500] — in fact, any text can be added after the reference, as [6, Any text you might want]. Now you can even cite dissertations, like [7].

   The easiest way to assure consistency with the formatting of each entry is to retrieve them from the same website (InspireHEP, NASA/ADS, …).

   As a final note, in the *Bibliography*, the title will also be an hyperlink to the URL, DOI, ISBN, or ISSN, **in that order of priority**. Therefore, if an article has an open-access version, include the URL in the `.bib` file, and it will be used for the hyperlink.

1.2   Useful links

To take the biggest advantage possible of this template it is useful to know the ins and outs of LaTeX. This usually takes time, but it is not a daunting task. For a start, the Overleaf website contains some straightforward tutorials on how to edit LaTeX files. After the basics, the LaTeX stackexchange can help you with more specific problems – there is almost always someone with a similar problem!

1.3   How to compile this template

When making changes to the *List of Abbreviations*, *List of Symbols*, or the *Bibliography*, one must recreate some auxiliary files in order for the changes to take effect.

1.3.1   TeXstudio

In *TeXstudio*, this can be achieved by:

- Altering the glossary;

- Compiling the `.tex` file [F5];

- Producing the glossary auxiliary files [F9];

- Compiling the `.tex` file **again** [F5].

Note, if the change involves erasing a line from the *List of Abbreviations* (*Glossary*), the last two steps may need to be repeated (keep producing the glossary files and recompiling the project). Besides the hotkeys, these commands can be found in the *Tools* menu in the upper bar.

For the *Bibliography*, a similar procedure is required. This is also true for the *List of Symbols* (*Nomenclature*), with an additional caveat that the compilation command in *Options → Configure TeXstudio → Commands → Make Index* should be changed to one of the following

```
makeindex.exe %.nlo -s nomencl.ist -o %.nls
makeindex %.nlo -s nomencl.ist -o %.nls
```

on Windows and Linux systems respectively. The command to build the auxiliary files for the nomenclature can be found in *Tools*, named *Index* (you can define a hotkey in *Configure TeXstudio*).

1.3.2   Overleaf

In *Overleaf*, it is enough to delete the cached files before recompiling the project. This can be done by clicking the *Logs and output files* button (which displays the compilation errors and warnings), followed by the *Trash Can* icon. Note, this is not necessary when deleting or re-adding an element of the glossary, only when making changes.

This behaviour was verified on *Overleaf*, with the *pdfLaTeX* compiler, using TeX Live version 2020.

Chapter 2

A Sample Chapter

This chapter contains some examples of equations, figures, and tables with a suggested style.

2.1   Some Text

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

2.2   Some Equations, even in section titles, $E = h\nu$

The following sections contain various examples of typeset equations, such as $\left(\partial_\mu \partial^\mu - m^2\right)\phi = 0$, $\sqrt{x^2 + 1}$, $f_{p/h}(x, Q^2)$, or $\tau_{\mathrm{form}}^{-1} \propto z\,\theta^2$. This section also exemplifies how to use math in section titles, without having problems in the table of contents.

2.2.1   Single Line, Single Label Equation

$$\mathrm{d}\ln\rho^2\,\mathrm{d}z = \det\begin{bmatrix} 1 & f'(z)/f(z) \\ 0 & 1 \end{bmatrix}\mathrm{d}\ln\mu^2\,\mathrm{d}z = \mathrm{d}\ln\mu^2\,\mathrm{d}z\,. \tag{2.1}$$

2.2.2   Multiple Line, Single Label Equation

$$
\begin{aligned}
\mathscr{L}_{\mathrm{classical}} &= \overline{\psi}(\mathrm{i}\slashed{D} - \mathsf{M})\psi - \frac{1}{4}F_{\mu\nu}^a F^{a,\mu\nu}\,, \quad \text{with} \\
D_\mu &= \partial_\mu - \mathrm{i}\,g\,\mathsf{T}^a A_\mu^a\,, \\
F_{\mu\nu}^a &= \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + g\,f^{abc}A_\mu^b A_\nu^c\,.
\end{aligned}
\tag{2.2}
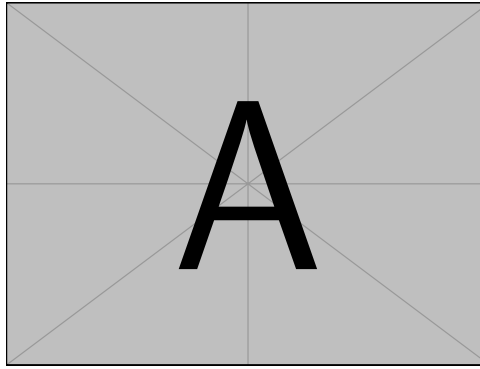$$

2.2.3 Multiple Line, Multiple Label Equation

$$\frac{1}{(-g)}\mathcal{M}_{\mathcal{B}\to q\bar{q}g} = \varepsilon_\mu(k)^*\,\bar{u}(p_1)\mathsf{T}^a_{ij}\left(\gamma^\mu\frac{\slashed{k}+\slashed{p}_1+m}{(p_1+k)^2-m^2}\mathcal{B} - \mathcal{B}\frac{\slashed{k}+\slashed{p}_2-m}{(p_2+k)^2-m^2}\gamma^\mu\right)v(p_2) \tag{2.3a}$$

$$= \bar{u}(p_1)\,\mathcal{B}\,v(p_2)\,\varepsilon_\mu(k)^*\left(\frac{p_1^\mu}{p_1\cdot k} - \frac{p_2^\mu}{p_2\cdot k}\right)\mathsf{T}^a_{ij} + \bar{u}(p_1)\left(\frac{\slashed{\varepsilon}^*\,\slashed{k}\,\mathcal{B}}{2\,p_1\cdot k} - \frac{\mathcal{B}\,\slashed{k}\,\slashed{\varepsilon}^*}{2\,p_2\cdot k}\right)v(p_2)\mathsf{T}^a_{ij}. \tag{2.3b}$$

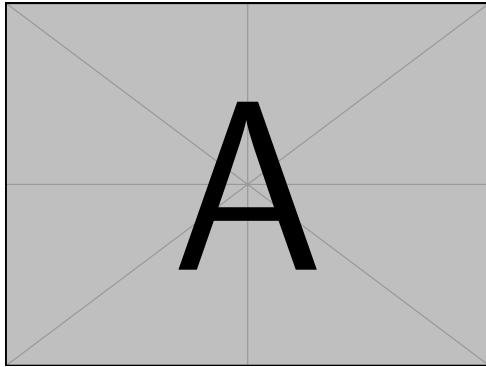Here we see equation (2.3), with special emphasis on line (2.3b).

2.3 Some Figures
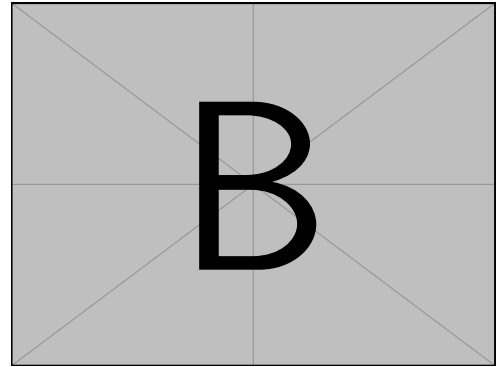
2.3.1 Single Figure

Figure 2.1: A figure, with a caption. A very long caption. A really rather long caption, to show off the line width for captions.

2.3.2 Side By Side
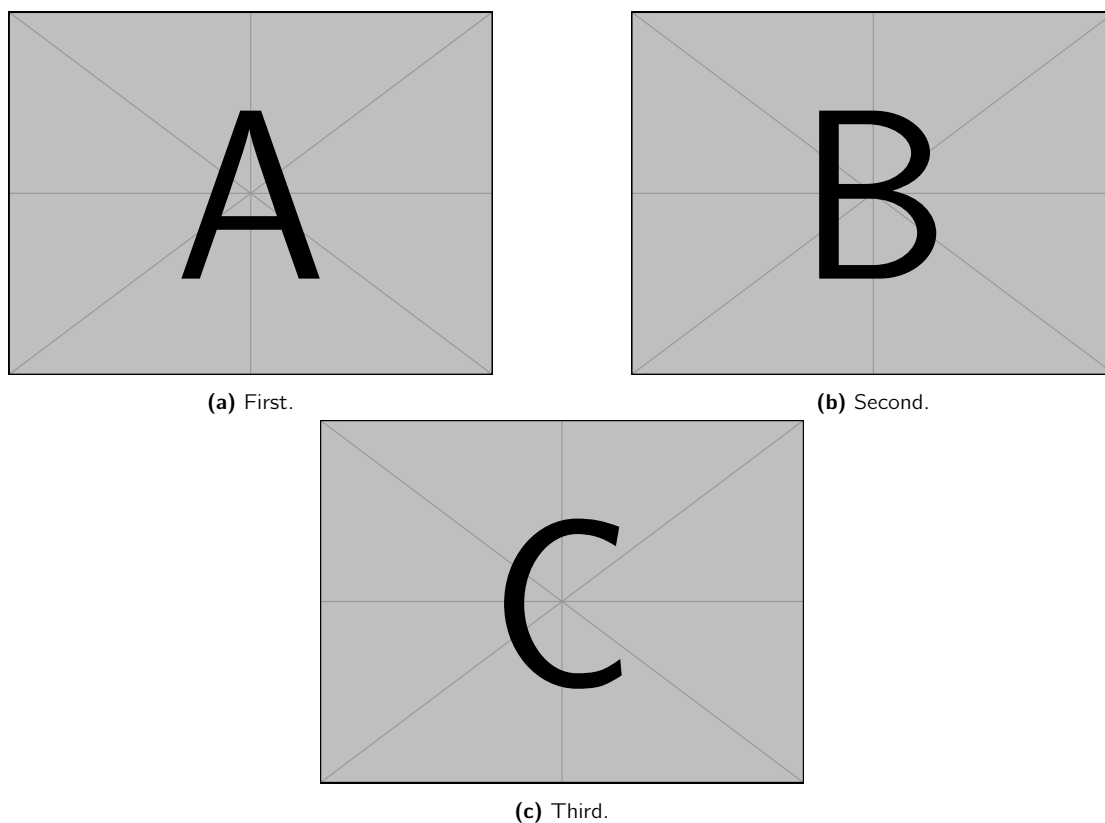

(a) A sub-figure.

(b) Another sub-figure.

Figure 2.2: Two different sub-figures.

In 2.2, we have two images, 2.2a and 2.2b, side by side.

2.3.3 Three Figures

(a) First.

(b) Second.

(c) Third.

Figure 2.3: Three sub-figures, in the same image.

2.4 Some Tables

2.4.1 A Simple Table

Measurement	1	2	3	4	5	6
Experiment 1	4.20	27.13	70.06	133.35	180.42	267.73
Experiment 2	6.34	37.72	99.00	132.12	201.62	221.37
Experiment 3	10.62	64.53	171.98	282.91	335.09	541.63

Table 2.1: Table with a simple structure.

2.4.2 A More Complicated Table

Analysis Methods	Data Sets			
	Data Set 1	Data Set 2	Data Set 3	Data Set 4
Method 1	5.09	4.15	6.02	8.49
Method 2	2.19	2.09	4.44	4.74

Table 2.2: Table with a somewhat less simple structure.

Bibliography

[1] A. Einstein, "On the electrodynamics of moving bodies", *Annalen Phys.*, vol. 17, pp. 891–921, 1905.

[2] R. Mertig, M. Bohm, and A. Denner, "FEYN CALC: Computer algebraic calculation of Feynman amplitudes", *Comput. Phys. Commun.*, vol. 64, pp. 345–359, 1991.

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[4] V. Shtabovenko, R. Mertig, and F. Orellana, "FeynCalc 9.3: New features and improvements", *Comput. Phys. Commun.*, vol. 256, p. 107 478, 2020. arXiv: 2001.04407 [hep-ph].

[5] Y. L. Dokshitzer, V. A. Khoze, A. H. Mueller, and S. I. Troian, *Basics of perturbative QCD*. 1991.

[6] M. E. Peskin and D. V. Schroeder, *An introduction to quantum field theory*. Westview, 1995.

[7] R. P. Feynman, "The principle of least action in quantum mechanics", PhD thesis, Princeton U., 1942.

Appendix A

An Appendix

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.