



UNIVERSITÀ DI PISA

HERE GOES THE THESIS TITLE
THESIS SUBTITLE (IF NEEDED)

Submitted in partial fulfilment of the requirements for the
MASTER OF SCIENCE DEGREE IN
NUCLEAR ENGINEERING

CANDIDATE

Name Surname

SUPERVISORS

Prof. Name Surname

Prof. Name Surname

Prof. Name Surname

Dedication

Abstract

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Acknowledgments

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1 | Chapter Title

1.1 Sections and subsections

Sections and subsections may appear inside a Chapter, as well as subsubsections, paragraphs and subparagraphs.

A section can be created by the command

```
\section{Title of the section}
```

A subsection is instead created by the command

```
\subsection{Title of the subsection}
```

Section and subsection numbering is turned off using `\section*{}` or `\subsection*{}`.

1.2 References

References can be provided through the *BiBTeX* program that allows to store them in a separate .bib file and formatted according to different styles.

Example of a book reference definition inside the biblio.bib file:

```
@book{zweifel1973,  
  title={Reactor Physics},  
  author={Zweifel, P.F.},  
  isbn={9780070735972},  
  lccn={72174628},  
  series={International student edition},  
  url={https://books.google.it/books?id=4yhRAAAAMAAJ},  
  year={1973},  
  publisher={McGraw-Hill}  
}
```

Example of an article reference definition inside the biblio.bib file:

```
@article{Romano201590,  
  title = {OpenMC: A state-of-the-art Monte Carlo  
    code for research and development},
```

```

journal = {Annals of Nuclear Energy},
volume = {82},
pages = {90-97},
year = {2015},
issn = {0306-4549},
doi = {https://doi.org/10.1016/j.anucene.2014.07.048},
author = {Paul K. Romano and Nicholas E. Horelik and Bryan R. Herman
         and Adam G. Nelson and Benoit Forget and Kord Smith},
keywords = {Monte Carlo, Neutron transport, OpenMC, Parallel, XML, HDF5}
}

```

To cite those references in the text you can use `\cite{zweifel1973}` or `\cite{Romano201590}` and they will appear as ? and ?.

1.3 Equations

Some examples of mathematical equations.

Linear system of equations:

$$\begin{cases} a_0x + a_1y + a_2z = q_1 & (1.1a) \\ b_0x + b_1y + b_2z = q_2 & (1.1b) \\ c_0x + c_1y + c_2z = q_3 & (1.1c) \end{cases}$$

In the above system (??), each equation has his own label, (??), (??) and (??), namely. If distinct label are not necessary, the system can be given a single label as follows

$$\begin{cases} a_0x + a_1y + a_2z = q_1 \\ b_0x + b_1y + b_2z = q_2 \\ c_0x + c_1y + c_2z = q_3 \end{cases} \quad (1.2)$$

The integro-differential neutron transport equation is too long to fit in one line, then can be split on more lines keeping a single label as follows

$$\begin{aligned} \frac{\partial}{\partial t} n(\mathbf{r}, v\mathbf{\Omega}, t) + v\mathbf{\Omega} \cdot \nabla n(\mathbf{r}, v\mathbf{\Omega}, t) + \Sigma_t(\mathbf{r}, v) v n(\mathbf{r}, v\mathbf{\Omega}, t) = \\ \int_0^\infty dv' \int_{4\pi} \Sigma_s(\mathbf{r}, v'\mathbf{\Omega}' \rightarrow v\mathbf{\Omega}) v' n(\mathbf{r}, v'\mathbf{\Omega}', t) d\mathbf{\Omega}' \\ + \frac{\chi(v)}{4\pi} \int_0^\infty dv' \int_{4\pi} \nu \Sigma_f(\mathbf{r}, v') v' n(\mathbf{r}, v'\mathbf{\Omega}', t) d\mathbf{\Omega}' \\ + S(\mathbf{r}, v\mathbf{\Omega}, t) \end{aligned} \quad (1.3)$$

To avoid any possible misunderstanding, it is indeed fundamental to write the mathematical formulas in a correct form. In that view, the reading of ? is strongly suggested.

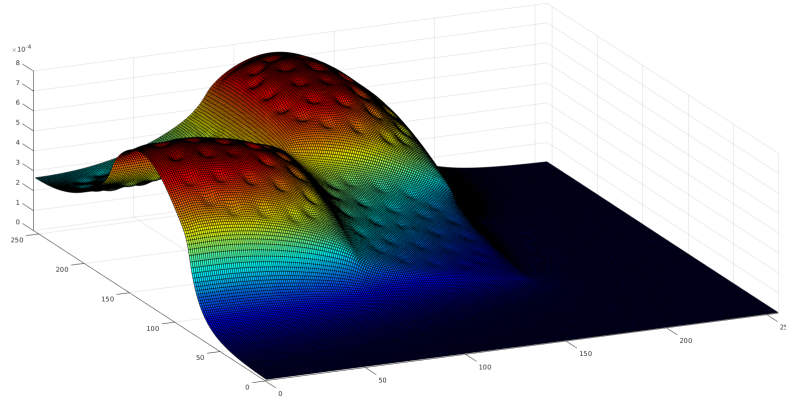


Figure 1.1: Detailed distribution of fast neutron flux.

1.4 Figures

Each figure should be numbered and referenced in the text. Caption should appear below the figure. Many graphics file formats can be used with \LaTeX . Preferable are the followings:

- PDF: for vector graphics (resizeable at pleasure without loss of resolution);
- JPG: for photos;
- PNG: for other kinds of raster graphics.

Here, Figure ?? is obtained using a PDF file.

Figures ?? and ?? give an example of the quality obtainable with different graphic formats. Both figures show the binding energy per nucleon, although the first is from a .pdf file while the second is from a .png file (without compression).

Crowded figures may be tiring; only relevant data should be included.

1.5 Tables

Tables are handy for reporting information, data, and results in a compact and efficient form. However, care should be taken so that a reader can understand the table content even without reading the thesis text. In other words, captions, column, and row titles should be comprehensive. Unlike figures, the table caption should appear above it. Remember that clarity of data reporting must be the first objective. Thus, for example, do not use a coloured cell background if it is not necessary.

\LaTeX offers the possibility of creating a wide variety of table formats. A good description of how tables can be formatted is given in (?).

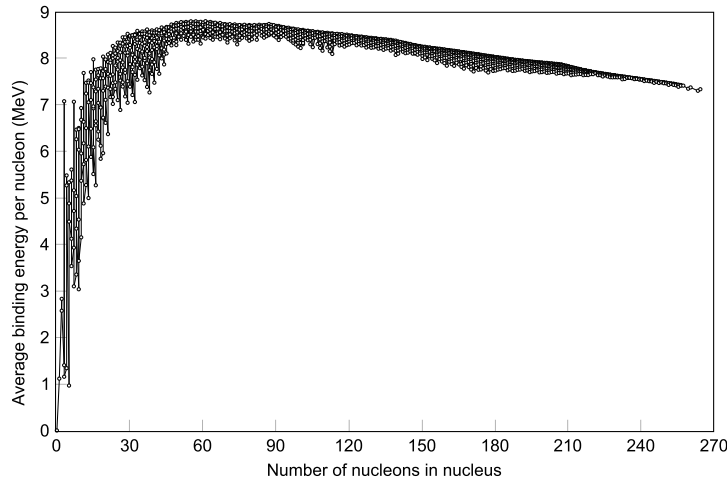


Figure 1.2: Binding energy per nucleon: from .pdf file.

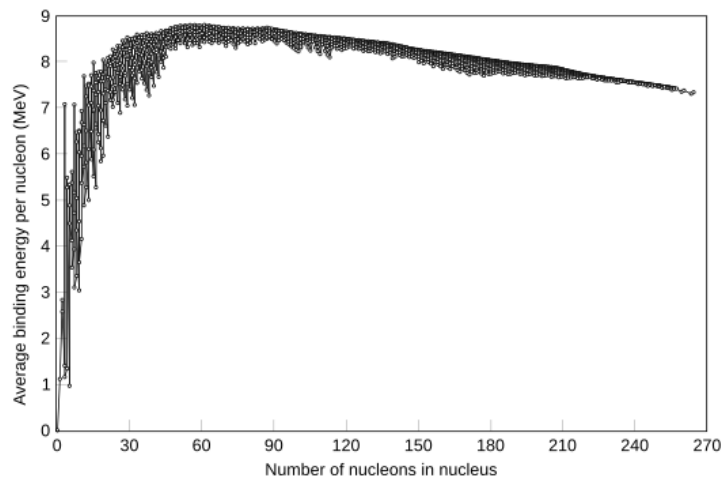


Figure 1.3: Binding energy per nucleon: from .png file.

Table ?? and ?? show two quite different formatting that can be achieved using the table environments in \LaTeX . In particular, the first is obtained with the `ctable` environment, while the second with the `table` environment.

1.6 Latex document review

The review process is a fundamental step for the thesis finalization. As such it would be important to have a tool that might help performing the reviewing of the document in a fashion similar to that offered by other commonly used word processors, *e.g.* Microsoft Word[®] or LibreOffice Writer.

Although not as performant as the track change tools available in the two already cited word processors, the \LaTeX *xreview* package is, as stated by the author, “an attempt to make the painful process of reviewing a \LaTeX document easy, or, at least, *a little* less

Table 1.1: Estimate of the multiplication constant k for the 3D LMFR core problem. PARTISN results are shown as a function of the number of fine meshes used, M . BERM-A2 results are shown as a function of the Legendre expansion order of the partial currents, L .

Code	M	L	k	Δk (pcm)	CPU time (s)
PARTISN	8		0.94619	-14	599
	16		0.94633 ^a	-	5373
BERM-A2		2	0.94557	-76	72
		3	0.94570	-63	163
		4	0.94577	-56	439

^a Reference value.

Table 1.2: 3D, 7-groups, UOX/MOX core problem: axially-averaged assembly fission power. The maximum discrepancy is shown in red.

0.9094	0.7551	BERM			k	$\Delta(\text{pcm})$
0.9054	0.7518	POL3D		BERM	1.156324	-
-0.44%	-0.44%	Error		POL3D	1.156436	11.2
1.8194	1.6956	1.3658	0.8670			
1.8232	1.6907	1.3636	0.8634			
0.21%	-0.29%	-0.16%	-0.41%			
3.2742	3.1112	2.4895	1.6675	1.1095		
3.2727	3.1152	2.4930	1.6621	1.1026		
-0.05%	0.13%	0.14%	-0.32%	-0.62%		
4.5941	4.1973	3.2070	2.5587	1.9764	1.1388	
4.5960	4.1987	3.2099	2.5587	1.9726	1.1316	
0.04%	0.03%	0.09%	0.00%	-0.20%	-0.63%	
...	

painful.”

Just to make a simple example, let us consider the following text:

“For a completely uniform medium, the diffusion operator A is defined as

$$A \cdot = vD\nabla^2\phi \cdot - v\Sigma_s \cdot$$

and it can be shown that it has the same eigenvectors and eigenvalues of the ∇^2 operator.”

Once reviewed, the command `\showchanges` makes visible all the changes:

For a ~~completely~~ uniform medium, the diffusion operator **A** is defined as

$$A \cdot = vD\nabla^2\phi \cdot - v\Sigma_{\textcolor{red}{s}\textcolor{blue}{a}} \cdot$$

and it can be shown that it has the same ~~eigenvectors~~ **eigenfunctions** and eigenvalues of the ~~∇^2~~ **Laplace** operator, ∇^2 .

Vice versa, the command `\showclean` let's hide them all :

reviewer

C1:

Shall

we also

add that

it is sym-

metric?

For a uniform medium, the diffusion operator A is defined as

$$A \cdot = vD\nabla^2\phi \cdot - v\Sigma_a \cdot$$

and it can be shown that it has the same eigenfunctions and eigenvalues of the Laplace operator, ∇^2 .

The L^AT_EX syntax of the above sentence looks like:

For a `\removed{completely}` uniform medium, `\reviewercomment{the diffusion operator`
`A}{Shall we also add that it is symmetric?}` is defined as
`\[\operatorname{A}\cdot = vD \nabla^2 \phi \cdot - v\Sigma_{\changed{s}{a}} \cdot \]`
 and it can be shown that it has the same `\changed{eigenvectors}{eigenfunctions}`
 and eigenvalues of the `\changed{\nabla^2}{Laplace}` operator`\added{, \nabla^2.}`

To see all the available options please refer to the *xreview* package documentation ([link](#)).

2 | Conclusion

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A | Appendix A title

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List of acronyms (optional)

Acronym	Definition
BOC	Beginning of cycle
EOC	End of cycle
HZP	Hot zero power
...	...

List of symbols (optional)

Symbol	Definition	Units (SI)
Φ	neutron flux	$cm^{-2}s^{-1}$
...