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COMBUSTIBILI NUCLEARI PER REATTORI DI
TERZA E QUARTA GENERAZIONE

ABSTRACT

We summarize the characteristics of third and fourth generation nuclear reactors and examine in detail the corresponding nuclear fuels

RIASSUNTO

Si ricapitolano le caratteristiche dei reattori di terza e quarta generazione e si esaminano in dettaglio le caratteristiche dei relativi combustibili nucleari

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ACRONYMS

API Application Programming Interface

UML Unified Modeling Language

Parte I

REATTORI NUCLEARI DI TERZA E QUARTA GENERAZIONE

INTRODUZIONE

1.1 REATTORI NUCLEARI

I reattori nucleari sono nati negli anni '50. Il primo reattore nucleare sperimentale a essere collegato a una rete elettrica fu l'impianto da 5 MW di Obninsk, acceso il 27 giugno 1954. Seguirono gli impianti commerciali di Calder Hall presso Sellafield in Inghilterra, nel 1956, con una capacità di 50 MW, seguito un anno dopo dal primo reattore statunitense, l'impianto di Shippingport in Pennsylvania [?].

1.2 LA TERZA GENERAZIONE, (GEN3)

i reattori di terza generazione

1.3 LA GENERAZIONE INTERMEDIA (GEN3+)

i reattori di terza generazione evoluta

1.4 LA QUARTA GENERAZIONE

i reattori di quarta generazione

A very important factor for successful thesis writing is the organization of the material. This template suggests a structure as the following:

- `Chapters/` is where all the “real” content goes in separate files such as `Chapter01.tex` etc.
- `FrontBackMatter/` is where all the stuff goes that surrounds the “real” content, such as the acknowledgments, dedication, etc.
- `gfx/` is where you put all the graphics you use in the thesis. Maybe they should be organized into subfolders depending on the chapter they are used in, if you have a lot of graphics.
- `Bibliography.bib`: the Bib_TE_X database to organize all the references you might want to cite.
- `classicthesis.sty`: the style definition to get this awesome look and feel.

You can use these margins for summaries of the text body...

- `ClassicThesis.tcp` a \TeX nicCenter project file. Great tool and it's free!
- `ClassicThesis.tex`: the main file of your thesis where all gets bundled together.
- `classicthesis-ldpkg.sty`: a central place to load all nifty packages that are used. The package has the following options available:
 - `nochapters`, which defaults to `false`. Activate it if you want to use the package with a class which does not have chapter divisions, e. g., an article.
 - `backref`, which also defaults to `false`. Activate it if you do want to show in the bibliography on which page(s) each reference was cited. for an example of the default setting.

This should get you started in no time.

1.5 STYLE OPTIONS

There are a couple of options for `classicthesis.sty` that allow for a bit of freedom concerning the layout:

...or your supervisor might use the margins for some comments of her own while reading.

- `drafting`: prints the date and time at the bottom of each page, so you always know which version you are dealing with. Might come in handy not to give your Prof. that old draft.
- `eulerchapternumbers`: use figures from Hermann Zapf's Euler math font for the chapter numbers. By default, old style figures from the Palatino font are used.
- `linedheaders`: changes the look of the chapter headings a bit by adding a horizontal line above the chapter title. The chapter number will also be moved to the top of the page, above the chapter title.
- `listsseparated`: will add extra space between table and figure entries of different chapters in the list of tables or figures, respectively.
- `totaligned`: aligns the whole table of contents on the left side. Some people like that, some don't.
- `subfig(ure)`: is passed to the `tocloft` package to enable compatibility with the `subfig(ure)` package.
- `nochapters`: allows to use the look-and-feel with classes that do not use chapters, e. g., for articles. Automatically turns off a couple of other options: `eulerchapternumbers`, `linedheaders`, `listsseparated`, and `parts`.

- `beramono`: loads Bera Mono as typewriter font. (Default setting is using the standard CM typewriter font.)
- `eulermath`: loads the awesome Euler fonts for math. (Palatino is used as default font.)
- `parts`: if you use Part divisions for your document, you should choose this option. It provides you with the command `\myPart{}` which takes care of the style and the entry into the Table of Contents. (Cannot be used together with `nochapters`.)
- `a5paper`: adjusts the page layout according to the global `a5paper` option (*experimental* feature).
- `minionpro`: sets Robert Slimbach’s Minion as the main font of the document. The textblock size is adjusted accordingly.
- `pdfspacing`: makes use of `pdftex`’ letter spacing capabilities via the `microtype` package.¹ This fixes some serious issues regarding math formulæ etc. (e. g., “ß”) in headers.
- `minionprospacing`: uses the internal `textssc` command of the MinionPro package for letter spacing. This automatically enables the `minionpro` option and overrides the `pdfspacing` option.
- `dottedtoc`: sets `pagenumbers` flushed right in the table of contents.
- `listings`: loads the `listings` package (if not already done) and configures the List of Listings accordingly.
- `manychapters`: if you need more than nine chapters for your document, you might not be happy with the spacing between the chapter number and the chapter title in the Table of Contents. This option allows for additional space in this context. However, it does not look as “perfect” if you use `\parts` for structuring your document.

The best way to figure these options out is to try the different possibilities and see, what you and your supervisor like best.

To make things in general easier, `classicthesis-ldpkg.sty` contains some useful commands that might help you.

1.6 FUTURE WORK

So far, this is a quite stable version that served a couple of people well during their thesis time. However, some things are still not as they should be. Proper documentation in the standard

¹ Use `microtype`’s `DVIoutput` option to generate DVI with `pdftex`.

format is still missing. In the long run, the style should probably be published separately, with the template bundle being only an application of the style. Alas, there is no time for that at the moment...it could be a nice task for a small group of L^AT_EXnicians.

Please do not send me email with questions concerning L^AT_EX or the template, as I do not have time for an answer. But if you have comments, suggestions, or improvements for the style or the template in general, do not hesitate to write them on that postcard of yours.

1.7 LICENSE

GNU GENERAL PUBLIC LICENSE: This program is free software; you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation; either version 2 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but *without any warranty*; without even the implied warranty of *merchantability* or *fitness for a particular purpose*. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this program; see the file COPYING. If not, write to the Free Software Foundation, Inc., 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA.

1.8 BEYOND A THESIS

It is easy to use the layout of `classicthesis.sty` without the framework of this bundle. To make it even easier, this section offers some plug-and-play-examples.

The L^AT_EX-sources of these examples can be found in the folder with the name Examples. They have been tested with `latex` and `pdflatex` and are easy to compile. To assure you even a bit more, PDFs built from the sources can also be found the folder.

Listing 1: An Article

```
% article example for classicthesis.sty
\documentclass[10pt,a4paper]{scrartcl} % KOMA-Script article
\usepackage{lipsum}
\usepackage{url}
%\usepackage[nochapters]{../classicthesis-ldpkg}
\usepackage[nochapters,minionprospacing]{../classicthesis} %
  nochapters

\begin{document}
  \title{\rmfamily\normalfont\spacedallcaps{the title}}
```

```

\author{\spacedlowsmallcaps{tyler durden}}
\date{} % no date

\maketitle

\begin{abstract}
  \noindent\lipsum[1]
\end{abstract}

\tableofcontents

\section{A Section}
\lipsum[1]
\subsection{A Subsection}
\lipsum[1]
\subsection{A Subsection}

\section{A Section}
\lipsum[1]

% bib stuff
\nocite{*}
\addtocontents{toc}{\protect\vspace{\beforebibskip}}
\addcontentsline{toc}{section}{\refname}
\bibliographystyle{plain}
\bibliography{../Bibliography}
\end{document}

```

Listing 2: A Book

```

% book example for classicthesis.sty
\documentclass[12pt,a5paper,footinclude]{scrbook} % KOMA-
  Script book
\usepackage[T1]{fontenc}
\usepackage{lipsum}
\usepackage[linedheaders,parts]{../classicthesis} % ,
  manychapters
\usepackage[osf]{libertine}
%\hypersetup{linktocpage=true,bookmarksnumbered=true,
  pageanchor=true,hypertextnames=false,naturalnames=true,
  plainpages=false}

\begin{document}
  \tableofcontents

  % use \cleardoublepage here to avoid problems with
    pdfbookmark
  \cleardoublepage\part{Test Part}
  \chapter{Test Chapter}
  \lipsum[1]

  \section{A Section}
  \lipsum[1]

```

```

\chapter{Test Chapter}
\lipsum[1]

\section{A Section}
\lipsum[1]

\appendix
\cleardoublepage\part{Appendix}
\chapter{Appendix Chapter}
\lipsum[1]

\section{A Section}
\lipsum[1]

\end{document}

```

Listing 3: A Curriculum Vitæ

```

% cv example for classicthesis.sty
\documentclass[10pt,a4paper]{scrartcl}
\usepackage[LabelsAligned]{currvita} % nice cv style
\usepackage{url}
\usepackage[nochapters]{../classicthesis}

\renewcommand*{\cvheadingfont}{\LARGE\color{Maroon}}
\renewcommand*{\cvlistheadingfont}{\large}
\renewcommand*{\cvlabelfont}{\qquad}

\begin{document}
  \begin{cv}{\spacedallcaps{Curriculum Vitæ}}
    %\pdfbookmark[1]{Pers\onliche Daten}{PersDat}
    \begin{cvlist}{\spacedlowsmallcaps{Pers\onliche
      Daten}}\label{PersDat}
      \item Andr'e Miede
      \item Geboren am \dots \\\
        Europ"aer, Deutsche Staatsb"urgerschaft
      \item \url{http://www.miede.de} \\\
        \url{https://www.xing.com/profile/Andre_
          Miede}
    \end{cvlist}

    %\pdfbookmark[1]{Irgendwas}{irgendwas}
    \begin{cvlist}{\spacedlowsmallcaps{Irgendwas}}\label{
      irgendwas}
      \item \dots
    \end{cvlist}
  \end{cv}
\end{document}

```

Parte II

COMBUSTIBILI PER I REATTORI DI TERZA GENERAZIONE

EXAMPLES

Ei choro aeterno antiopam mea, labitur bonorum pri no ? [?].
His no decore nemore graecis. In eos meis nominavi, liber soluta
vim cu. Sea commune suavitate interpretaris eu, vix eu libris
efficiantur.

2.1 A NEW SECTION

Illo principalmente su nos. Non message *occidental* angloroma-
nic da. Debitas effortio simplicate sia se, auxiliar summarios
da que, se avantiate publicationes via. Pan in terra summarios,
capital interlingua se que. Al via multo esser specimen, campo
responder que da. Le usate medical addresses pro, europa origine
sanctificate nos se.

Examples: *Italics*, ALL CAPS, SMALL CAPS, LOW SMALL
CAPS.

2.1.1 Test for a Subsection

Lorem ipsum at nusquam appellantur his, ut eos erant homero
concludaturque. Albucius appellantur deterruisset id eam, vi-
vendum partiendo dissentiet ei ius. Vis melius facilisis ea, sea id
convenire referrentur, takimata adolescens ex duo. Ei harum argu-
mentum per. Eam vidit exerci appetere ad, ut vel zzril intellegam
interpretaris.

Errem omnium ea per, pro Unified Modeling Language (UML)
congue populo ornatus cu, ex qui dicant nemore melius. No
pri diam iriure euismod. Graecis eleifend appellantur quo id. Id
corpora inimicus nam, facer nonummy ne pro, kasd repudiandae
ei mei. Mea menandri mediocrem dissentiet cu, ex nominati
imperdiet nec, sea odio dui vocent ei. Tempor everti appareat cu
ius, ridens audiam an qui, aliquid admodum conceptam ne qui.
Vis ea melius nostrum, mel alienum euripidis eu.

Ei choro aeterno antiopam mea, labitur bonorum pri no. His
no decore nemore graecis. In eos meis nominavi, liber soluta vim
cu.

2.1.2 Autem Timeam

Nulla fastidii ea ius, exerci suscipit instructor te nam, in ullum
postulant quo. Congue quaestio philosophia his at, sea odio
autem vulputate ex. Cu usu mucus iisque voluptua. Sit maiorum

*Note: The content of
this chapter is just
some dummy text. It
is not a real
language.*

propriae at, ea cum Application Programming Interface (API) primis intellegat. Hinc cotidieque reprehendunt eu nec. Autem timeam deleniti usu id, in nec nibh altera.

2.2 ANOTHER SECTION IN THIS CHAPTER

Non vices medical da. Se qui peano distinguer demonstrate, personas internet in nos. Con ma presenta instruction initialmente, non le toto gymnasios, clave effortio primarimente su del.¹

Sia ma sine svedese americas. Asia ? [?] representantes un nos, un altere membros qui.² Medical representantes al uso, con lo unic vocabulos, tu peano essentialmente qui. Lo malo laborava anteriormente uso.

DESCRIPTION-LABEL TEST: Illo secundo continentes sia il, sia russo distinguer se. Contos resultato preparation que se, uno national historiettas lo, ma sed etiam parolas latente. Ma unic quales sia. Pan in patre altere summario, le pro latino resultato.

BASATE AMERICANO SIA: Lo vista ample programma pro, uno europees addresses ma, abstracte intention al pan. Nos duce infra publicava le. Es que historia encyclopedia, sed terra celos avantiate in. Su pro effortio appellate, o.

Tu uno veni americano sanctificate. Pan e union linguistic ? [?] simplicate, traducite linguistic del le, del un apprende denomination.

2.2.1 *Personas Initialmente*

Uno pote summario methodicamente al, uso debe nomina hereditage ma. Iala rapide ha del, ma nos esser parlar. Maximo dictionario sed al.

2.2.1.1 *A Subsubsection*

Deler utilitate methodicamente con se. Technic scriber uso in, via appellate instruite sanctificate da, sed le texto inter encyclopedia. Ha iste americas que, qui ma tempore capital.

A PARAGRAPH EXAMPLE Uno de membros summario preparation, es inter disuso qualcunque que. Del hodie philologos occidental al, como publicate litteratura in web. Veni americano ? [?] es con, non internet millennios secundarimente ha. Titulo

¹ Uno il nomine integre, lo tote tempore anglo-romanice per, ma sed practice philologos historiettas.

² De web nostre historia angloromanice.

LABITUR BONORUM PRI NO	QUE VISTA	HUMAN
fastidii ea ius	germano	demonstratea
suscipit instructor	titulo	personas
quaestio philosophia	facto	demonstrated ?

Tabella 1: Autem timeam deleniti usu id. ?

utilitate tentation duo ha, il via tres secundarimente, uso americano inicialmente ma. De duo deler personas inicialmente. Se duce facite westeuropae web, [Tabella 1](#) nos clave articulos ha.

A. Enumeration with small caps (alpha)

B. Second item

Medio integre lo per, non ? [?] es linguas integre. Al web altere integre periodicos, in nos hodie basate. Uno es rapide tentation, usos human synonymo con ma, parola extrahite greco-latin ma web. Veni signo rapide nos da.

incorporate uno. Il web unic periodicos. Que usate scientia ma, sed tres unidirectional al, asia personas duo de. De sed russo nomina anteriormente, toto resultado anteriormente uno ma. Non se signo romanica technologia, un medio millennios con. publicationes con in, uno le parola tentation, pan de studio romanica greco-latin. Tu duo titulo debitas latente, que vista programma ma. Non tote tres germano se, lo parola periodicos non.

2.2.2 Linguistic Registrate

Veni introduction es pro, qui finalmente demonstrate il. E tam-ben anglese programma uno. Sed le debitas demonstrate. Non russo existe o, facite linguistic registrate se nos. Gymnasios, e. g., sanctificate sia le, publicate [Figura 1](#) methodicamente e qui.

Lo sed apprende instruite. Que altere responder su, pan ma, i. e., signo studio. [Figure 1b](#) Instruite preparation le duo, asia altere tentation web su. Via unic facto rapide de, iste questiones methodicamente o uno, nos al.



(a) Asia personas duo.



(b) Pan ma signo.



(c) Methodicamente o uno.



(d) Titulo debitas.

Figura 1: Tu duo titulo debitas latente.

Parte III

COMBUSTIBILI PER I REATTORI DI QUARTA GENERAZIONE

Ei choro aeterno antiopam mea, labitur bonorum pri no. His no decore nemore graecis. In eos meis nominavi, liber soluta vim cu. Sea commune suavitate interpretaris eu, vix eu libris efficiantur.

3.1 SOME FORMULAS

Due to the statistical nature of ionisation energy loss, large fluctuations can occur in the amount of energy deposited by a particle traversing an absorber element¹. Continuous processes such as multiple scattering and energy loss play a relevant role in the longitudinal and lateral development of electromagnetic and hadronic showers, and in the case of sampling calorimeters the measured resolution can be significantly affected by such fluctuations in their active layers. The description of ionisation fluctuations is characterised by the significance parameter κ , which is proportional to the ratio of mean energy loss to the maximum allowed energy transfer in a single collision with an atomic electron:

$$\kappa = \frac{\xi}{E_{\max}} ZNR$$

E_{\max} is the maximum transferable energy in a single collision with an atomic electron.

$$E_{\max} = \frac{2m_e\beta^2\gamma^2}{1 + 2\gamma m_e/m_x + (m_e/m_x)^2},$$

where $\gamma = E/m_x$, E is energy and m_x the mass of the incident particle, $\beta^2 = 1 - 1/\gamma^2$ and m_e is the electron mass. ξ comes from the Rutherford scattering cross section and is defined as:

$$\xi = \frac{2\pi z^2 e^4 N_{\text{Av}} Z \rho \delta x}{m_e \beta^2 c^2 A} = 153.4 \frac{z^2 Z}{\beta^2 A} \rho \delta x \quad \text{keV},$$

where

z	charge of the incident particle
N_{Av}	Avogadro's number
Z	atomic number of the material
A	atomic weight of the material
ρ	density
δx	thickness of the material

¹ Examples taken from Walter Schmidt's great gallery:
<http://home.vrweb.de/~was/mathfonts.html>

You might get unexpected results using math in chapter or section heads. Consider the pdfspacing option.

κ measures the contribution of the collisions with energy transfer close to E_{\max} . For a given absorber, κ tends towards large values if δx is large and/or if β is small. Likewise, κ tends towards zero if δx is small and/or if β approaches 1.

The value of κ distinguishes two regimes which occur in the description of ionisation fluctuations:

1. A large number of collisions involving the loss of all or most of the incident particle energy during the traversal of an absorber.

As the total energy transfer is composed of a multitude of small energy losses, we can apply the central limit theorem and describe the fluctuations by a Gaussian distribution. This case is applicable to non-relativistic particles and is described by the inequality $\kappa > 10$ (i.e., when the mean energy loss in the absorber is greater than the maximum energy transfer in a single collision).

2. Particles traversing thin counters and incident electrons under any conditions.

The relevant inequalities and distributions are $0.01 < \kappa < 10$, Vavilov distribution, and $\kappa < 0.01$, Landau distribution.

3.2 VARIOUS MATHEMATICAL EXAMPLES

If $n > 2$, the identity

$$t[u_1, \dots, u_n] = t[t[u_1, \dots, u_{n-1}], t[u_n, \dots, u_n]]$$

defines $t[u_1, \dots, u_n]$ recursively, and it can be shown that the alternative definition

$$t[u_1, \dots, u_n] = t[t[u_1, u_2], \dots, t[u_{n-1}, u_n]]$$

gives the same result.

COLOPHON

This thesis was typeset with \LaTeX 2 ϵ using Hermann Zapf's *Palatino* and *Euler* type faces (Type 1 PostScript fonts *URW Palladio L* and *FPL* were used). The listings are typeset in *Bera Mono*, originally developed by Bitstream, Inc. as "Bitstream Vera". (Type 1 PostScript fonts were made available by Malte Rosenau and Ulrich Dirr.)

The typographic style was inspired by ?'s genius as presented in *The Elements of Typographic Style* [?]. It is available for \LaTeX via CTAN as "**classicthesis**".

NOTE: The custom size of the textblock was calculated using the directions given by Mr. Bringhurst (pages 26–29 and 175/176). 10 pt Palatino needs 133.21 pt for the string "abcdefghijklmnopqrstuvwxy z ". This yields a good line length between 24–26 pc (288–312 pt). Using a "double square textblock" with a 1:2 ratio this results in a textblock of 312:624 pt (which includes the headline in this design). A good alternative would be the "golden section textblock" with a ratio of 1:1.62, here 312:505.44 pt. For comparison, DIV9 of the typearea package results in a line length of 389 pt (32.4 pc), which is by far too long. However, this information will only be of interest for hardcore pseudo-typographers like me.

To make your own calculations, use the following commands and look up the corresponding lengths in the book:

```
\settowidth{\abcd}{abcdefghijklmnopqrstuvwxy $z$ }  
\the\abcd\ % prints the value of the length
```

Please see the file `classicthesis.sty` for some precalculated values for Palatino and Minion.

145.86469pt