



**FIELD OF SCIENCE ENGINEERING AND TECHNOLOGY**

SCIENTIFIC DISCIPLINE INFORMATION AND COMMUNICATION TECHNOLOGY

## **DOCTORAL THESIS**

How to Write a Doctoral Thesis with  $\text{\LaTeX}$

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Biomedical Engineering

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*Special thanks to . . .*



# Abstract

Put the contents of your abstract here.



# Streszczenie

Tutaj należy umieścić streszczenie w języku polskim.





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# Chapter 1

## Introduction

The template was prepared as part of my course *L<sup>A</sup>T<sub>E</sub>X for Scientists* taught in the AGH Doctoral School. If you are unfamiliar with L<sup>A</sup>T<sub>E</sub>X and you don't want to attend the classes, you can learn L<sup>A</sup>T<sub>E</sub>X from materials available on the Internet, such as these books: [1], [3], [2]. All these books can be easily found on the Internet and are legally available. I recommend my book [5] to Polish-speaking students.



Figure 1.1: L<sup>A</sup>T<sub>E</sub>X praktyczny przewodnik

## 1.1 Class options

The *aghphd* provides 4 basic options:

**en** – Sets the language of the thesis to English – remember to set the *english* option for the *babel* package.

**pl** – Sets the language of the thesis to Polish – remember to set the *polish* option for the *babel* package.

**auxsup** – Includes information about the auxiliary (assistant) supervisor on the title page.

**secsup** – Includes information about the second (main) supervisor on the title page.

## 1.2 Basic information about thesis

The main file *phdthesis.tex* contains a sequence of commands that are used to define basic information about the thesis.

`\fieldofscience{}` – sets the field of science, the available options are:

- Engineering and technology
- Natural sciences
- Social sciences
- Humanities

`\discipline{}` – sets the scientific discipline, the available options are:

- Automation, electronic, electrical engineering and space technologies
- Information and communication technology
- Biomedical engineering
- Chemical engineering
- Civil engineering, geodesy and transport
- Materials engineering
- Mechanical engineering
- Environmental engineering, mining and energy
- Computer and information sciences,
- Mathematics,
- Chemical sciences,
- Physical sciences,
- Earth and related environmental sciences,
- Economy and finances

- Management and quality science,
- Sociology,
- Cultural and religious studies.

`\title{}` – sets the title of the thesis.

`\shorttitle{}` – sets the short title of the thesis – If the full title fits in the footer on one line use the full title of the thesis here. Otherwise, define an abbreviated version of the title.

`\author{}` – sets the PhD candidate first name and family name.

`\shortauthor{}` – sets the PhD candidate first name initial and family name – This version is used in the footer.

`\supervisor{}` – sets the first supervisor name with degrees.

`\secondsupervisor{}` – sets the second (main) supervisor or the auxiliary supervisor name with degrees.

`\faculty{}` – sets the faculty name, the available options are:

- Academic Centre for Materials and Nanotechnology
- Faculty of Applied Mathematics
- Faculty of Civil Engineering and Resource Management
- Faculty of Computer Science, Electronics, and Telecommunications
- Faculty of Drilling, Oil, and Gas
- Faculty of Electrical Engineering, Automatics, Computer Science, and Biomedical Engineering
- Faculty of Energy and Fuels
- Faculty of Foundry Engineering
- Faculty of Geo-Data Science, Geodesy, and Environmental Engineering
- Faculty of Geology, Geophysics, and Environmental Protection
- Faculty of Humanities
- Faculty of Management
- Faculty of Materials Science and Ceramics
- Faculty of Mechanical Engineering and Robotics
- Faculty of Metals Engineering and Industrial Computer Science
- Faculty of Non-Ferrous Metals
- Faculty of Physics and Applied Computer Science

`\date{}` – sets the year of the thesis preparation.

`\acknowledgements{}` – sets the acknowledgements that are typeset on a separate page..

## 1.3 Supervisors

If the dissertation was prepared under the supervision of only one supervisor, then you do not use any of the options *auxsup* or *secsup*. In this case, the information about the supervisor is typeset as follows:

Supervisor: Prof. Marcin Szpyrka, PhD, DSc

If the dissertation was prepared under the supervision of two main supervisors, then you should add the *secsup* class option. In this case, the information about the supervisors is typeset as follows:

Supervisor: Prof. Marcin Szpyrka, PhD, DSc  
Prof. Adam Iksiński, PhD, DSc

If the dissertation was prepared under the supervision of a main supervisor and an auxiliary supervisor, then you should add the *auxsup* class option. In this case, the information about the supervisors is typeset as follows:

First supervisor: Prof. Marcin Szpyrka, PhD, DSc  
Assisting supervisor: Prof. Adam Iksiński, PhD, DSc

## 1.4 Chapters and appendices

I recommend preparing each chapter and appendix in a separate *tex* file. In this template, examples of such files have names beginning with *chapter*. Add each of your chapters using the `\include{}` command. Chapter should be included after the *add your chapter here* comment.

If you want to add attachments, uncomment the `\appendix` command. Appendices are added in the same way as chapters, but the `\include{}` commands must be placed after the `\appendix` command.

## 1.5 Bugs

I prepared this class trying to do my best. There will probably be some errors in it anyway. If you notice something, just send me an email to [mszpyrka@agh.edu.pl](mailto:mszpyrka@agh.edu.pl)



## Chapter 2

# Thesis in Polish

Jeżeli rozprawa doktorska jest przytowywana w języku polskim, to należy wybrać opcję *pl* dla klasy dokumentu i opcję *polish* dla pakietu *babel*.

`\fieldofscience{}` – należy zastosować właściwą formę gramatyczną. Dopuszczalne wartości to:

- nauk inżynieryjno-technicznych
- nauk ścisłych i przyrodniczych
- nauk społecznych
- nauk humanistycznych

`\discipline{}` – lista dyscyplin naukowych:

- Automatyka, elektronika, elektrotechnika i technologie kosmiczne
- Informatyka techniczna i telekomunikacja
- Inżynieria biomedyczna
- Inżynieria chemiczna
- Inżynieria lądowa, geodezja i transport
- Inżynieria materiałowa
- Inżynieria mechaniczna
- Inżynieria środowiska, górnictwo i energetyka
- Informatyka
- Matematyka
- Nauki chemiczne
- Nauki fizyczne
- Nauki o Ziemi i środowisku
- Ekonomia i finanse
- Nauki o zarządzaniu i jakości

- Nauki socjologiczne
- Nauki o kulturze i religii

\facul ty{} – lista wydziałów:

- Akademickie Centrum Materiałów i Nanotechnologii
- Wydział Elektrotechniki, Automatyki, Informatyki i Inżynierii Biomedycznej
- Wydział Energetyki i Paliw
- Wydział Fizyki i Informatyki Stosowanej
- Wydział Geodezji Górniczej i Inżynierii Środowiska
- Wydział Geologii, Geofizyki i Ochrony Środowiska
- Wydział Humanistyczny
- Wydział Informatyki, Elektroniki i Telekomunikacji
- Wydział Inżynierii Lądowej i Gospodarki Zasobami
- Wydział Inżynierii Materiałowej i Ceramiki
- Wydział Inżynierii Mechanicznej i Robotyki
- Wydział Inżynierii Metali i Informatyki Przemysłowej
- Wydział Matematyki Stosowanej
- Wydział Metali Nieżelaznych
- Wydział Odlewnictwa
- Wydział Wiertnictwa, Nafty i Gazu
- Wydział Zarządzania

## Chapter 3

# Introduction to L<sup>A</sup>T<sub>E</sub>X

Even if you know the basics of L<sup>A</sup>T<sub>E</sub>X I suggest you read this chapter. It may save you nerves and many hours of wasted time.

### 3.1 Basic rules

- Whitespace characters, such as blank or tab, are treated uniformly as space by L<sup>A</sup>T<sub>E</sub>X. Several consecutive whitespace characters are treated as one space. Whitespace at the start of a line is generally ignored, and a single line break is treated as whitespace.
- To obtain a *non-breaking space*, use the tilde character instead of the space character.
- An empty line between two lines of text defines the *end of a paragraph*. Several empty lines are treated the same as one empty line.
- The characters \$ & % # \_ { } ~ ^ \ have a special meaning under L<sup>A</sup>T<sub>E</sub>X and cannot be entered directly in a text. These characters (except backslash) can be used in a document by using a prefix backslash, e.g. `\\$`.
- L<sup>A</sup>T<sub>E</sub>X is a high-quality typesetting system. Let us not try to improve it unless we really know what we are doing.
- L<sup>A</sup>T<sub>E</sub>X commands are case sensitive. Command names are terminated by a space, a number, or any other non-letter. L<sup>A</sup>T<sub>E</sub>X ignores whitespace after commands.
- Some commands require a parameter, which has to be given between curly brackets { } after the command name. Some commands take optional parameters, which are inserted after the command name in square brackets [ ].
- A L<sup>A</sup>T<sub>E</sub>X *environment* is a structure composed of two complementary commands `\begin{name}` and `\end{name}`. It is possible to use a command inside an environment, or to nest two or more environments. Arguments for an environment are placed after `\begin{name}`.
- ‘ ‘English’ ’ (“English”) quotation marks are produced by: 2 x *grave accent*, 2 x *vertical quote*.

- ‘ ‘ ,Polish’ ’ (‘,Polish’) quotation marks are produced by: 2 x *comma*, 2 x *vertical quote*.
- - (minus character) *hyphen* is used between inter-related words, e.g. inter-related.
- -- (2 x minus character) *en-dash* is used to indicate a ranges, e.g. 11–13.
- --- (3 x minus character) *em-dash* is used to show the extension of an expression, e.g. *Weather condition — like clear sky. . .*
- L<sup>A</sup>T<sub>E</sub>X assigns serial numbers to many environments or elements of an environment (e.g., table, figure, equation). This default numbering system eliminates the possibility of committing any mistake as may happen in manual numbering. A unique reference key is defined using the `\label{}` command. We can refer to the label using the `\ref{}` and `\pageref{}` commands. When defining labels, it is a good idea to give them prefixes specifying the type of referenced item, e.g. *eq*, *cha*, *sec*, *fig*, *def* etc. Spaces and diacritical marks may not be used in the labels!

## 3.2 Including graphics



Figure 3.1: L<sup>A</sup>T<sub>E</sub>X project logo.

Elements such as tables and figures are placed as so-called *floats*. Floats are created using the *figure* and *table* environments. Floats cannot be broken across pages. Any figure or table that does not fit on the current page is moved to a later page, while filling the current page with body text.

If a float cannot be placed on the current page, it is deferred either to the figures queue or the tables queue. When a new page is started, L<sup>A</sup>T<sub>E</sub>X first checks if it is possible to fill a special *float page* with floats from the queues. If this is not possible, the first float on each queue is treated as if it had just occurred in the text. If a figure cannot be placed it pushes all further figures to the end of the document.

*Placement specifier* (where the float is allowed to be moved): `\begin{table}[...]`

**h** – here at the very place in the text where it occurred,

**t** – at the top of a page,

**b** – at the bottom of a page,

**p** – on a special page containing only floats,

! – without considering most of the internal parameters, which could otherwise stop this float from being placed.



Figure 3.2: L<sup>A</sup>T<sub>E</sub>X project logo (black version) and Overleaf logo.

The label must be defined immediately after the *caption* command.

### 3.3 Tables

Table 3.1: Examples of Middle-earth peoples

| Wizards  | Elves   | Dwarves            | Men     | Hobbits       |
|----------|---------|--------------------|---------|---------------|
| Saruman  | Legolas | Gimli              | Aragorn | Bilbo Baggins |
| Gandalf  | Elrond  | Thorin Oakenshield | Boromir | Frodo Baggins |
| Radagast | Arwen   | Glóin              | Faramir | Sam Gamgee    |

Table 3.2: Examples of Middle-earth peoples

| Immortal |         | Mortal             |         |               |
|----------|---------|--------------------|---------|---------------|
| Wizards  | Elves   | Dwarves            | Men     | Hobbits       |
| Saruman  | Legolas | Gimli              | Aragorn | Bilbo Baggins |
| Gandalf  | Elrond  | Thorin Oakenshield | Boromir | Frodo Baggins |
| Radagast | Arwen   | Glóin              | Faramir | Sam Gamgee    |

Table 3.3: Examples of Middle-earth peoples

|          |         |               |
|----------|---------|---------------|
| Immortal | Wizards | Gandalf       |
|          | Elves   | Elrond        |
| Mortal   | Dwarves | Gimli         |
|          | Men     | Aragorn       |
|          | Hobbits | Frodo Baggins |

### 3.4 Mathematical expressions

A quadratic function  $f$  is a function of the form

$$f(x) = ax^2 + bx + c, \quad (3.1)$$

where  $a \neq 0$ .

L<sup>A</sup>T<sub>E</sub>X automatically selects the font size and spacing for each part of an equation:

$$\lim_{n \rightarrow \infty} \sum_{k=1}^n \frac{1}{k^2} = \frac{\pi^2}{6}$$

In in-line equations, some expressions are shrunk to fit the line  $\lim_{n \rightarrow \infty} \sum_{k=1}^n \frac{1}{k^2} = \frac{\pi^2}{6}$ .

If you need to place two or more equations one after the other, then use the *align* environment (see in the source file where the labels are defined):

$$|z| = 0 \iff z = 0, \quad (3.2)$$

$$|z| \geq 0, \quad (3.3)$$

$$\left| \frac{z_1}{z_2} \right| = \frac{|z_1|}{|z_2|}, \quad (3.4)$$

The *split* environment allows us to break long mathematical formulas into multiple lines. The & symbol indicates the left alignment of the expressions following it.

$$\begin{aligned} \int x^2 e^x dx &= x^2 e^x - 2 \int x e^x dx = \\ &= x^2 e^x - 2 \left( x e^x - \int e^x dx \right) = \\ &= x^2 e^x - 2x e^x + 2e^x + C \end{aligned} \quad (3.5)$$

Inside math mode any multi-letter name should be placed inside *mathit* command. For example, `$\mathit{off} + \mathit{on}$` produces this *off + on*, while `$off + on$` produces this *off + on* (look at those unnecessary ugly spaces around the letters *f*).

### 3.5 Definitions and theorems

All these examples are from my paper [4]. Examine the source file to see how label references are used.

**Definition 3.1.** Let  $p \in P$  be a place of an RTCP-net  $\mathcal{N}$  and let  $Out_A(p)$  denote the set of output arcs of the place  $p$ .

The *minimal accessibility age* of the place  $p$  is the number:

$$\delta_{min}(p) = \min_{a \in Out_A(p)} \left\{ \min_{b \in \mathcal{B}(T(a))} E_S(a)_b \right\}. \quad (3.6)$$

The *maximal accessibility age* of the place  $p$  is the number:

$$\delta_{max}(p) = \max_{a \in Out_A(p)} \left\{ \max_{b \in \mathcal{B}(T(a))} E_S(a)_b \right\}. \quad (3.7)$$

**Definition 3.2.** Let  $\mathcal{N}$  be an RTCP-net and let  $(M_1, S_1)$  and  $(M_2, S_2)$  be states of the net. The state  $(M_1, S_1)$  is said to *cover* the state  $(M_2, S_2)$  ( $(M_1, S_1) \simeq (M_2, S_2)$ ) iff  $M_1 = M_2$  and the following condition holds:

$$\forall p \in P: (S_1(p) = S_2(p)) \vee (S_1(p) \leq -\delta_{max}(p) \wedge S_2(p) \leq -\delta_{max}(p)). \quad (3.8)$$

**Proposition 3.1.** The *coverability relation*  $\simeq$  is an equivalence relation on  $\mathcal{R}(M_0, S_0)$ .

**Lemma 3.2.** Let  $(M_1, S_1)$  and  $(M_2, S_2)$  be the states of an RTCP-net  $\mathcal{N}$  such that  $(M_1, S_1) \simeq (M_2, S_2)$ . If  $(M_1, S_1) \xrightarrow{(t,b)} (M'_1, S'_1)$  and  $(M_2, S_2) \xrightarrow{(t,b)} (M'_2, S'_2)$ , then  $(M'_1, S'_1) \simeq (M'_2, S'_2)$ .

*Proof.*  $(M_1, S_1) \simeq (M_2, S_2)$ , hence, by definition 3.2,  $M_1 = M_2$  and the formula (3.8) holds for functions  $S_1$  and  $S_2$ . In both cases, the same transition  $t$  in the same binding  $b$  is fired, so it is evident that  $M'_1 = M'_2$ .

If  $p \in In(t) \cup Out(t)$ , then  $S'_1(p) = S'_2(p)$ . If  $p \notin In(t) \cup Out(t)$ , then  $S'_1(p) = S_1(p)$  and  $S'_2(p) = S_2(p)$ . Therefore, the states  $(M'_1, S'_1)$  and  $(M'_2, S'_2)$  cover each other.  $\square$

**Proposition 3.3.** Let  $(M_1, S_1)$  and  $(M_2, S_2)$  be the states of an RTCP-net  $\mathcal{N}$  such that  $(M_1, S_1) \simeq (M_2, S_2)$ . The following equality holds:

$$\mathcal{L}(M_1, S_1) = \mathcal{L}(M_2, S_2). \quad (3.9)$$

*Proof.* Suppose, a transition  $t$  is enabled in the state  $(M_1, S_1)$  in a binding  $b$  and  $(M_1, S_1) \xrightarrow{(t,b)} (M'_1, S'_1)$ .

$(M_1, S_1) \simeq (M_2, S_2)$  hence, by definition 3.2,  $M_1 = M_2$  and the formula (3.8) holds for functions  $S_1$  and  $S_2$ . Thus, the transition  $t$  is also enabled in the state  $(M_2, S_2)$  in the same binding  $b$ . Therefore, there exists a state  $(M'_2, S'_2)$  such that  $(M_2, S_2) \xrightarrow{(t,b)} (M'_2, S'_2)$ . Moreover, by lemma 3.2,  $(M'_1, S'_1) \simeq (M'_2, S'_2)$ . From the above considerations, by induction, we may now conclude that the statement (3.9) is satisfied.  $\square$





## **Chapter 4**

# **Concluding Remarks and Future Work**

Put the contents of your summary here.



# Bibliography

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- [2] E. Krishnan, editor. *LaTeX Tutorials – A primer*. Indian TeX Users Group, Trivandrum, India, 2003.
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