MSc Science and Technology of Nuclear Fusion

Report: requirements

In these pages we describe what we expect to see in your reports. This is not a detailed manual, but a description of the philosophy.

1. Preliminary remarks:

Focus on your own contribution

It is important that the report focuses on your own, original work. A bit of review of literature or existing theory is needed to provide the context and to give the reader the necessary basis. But keep this to the minimum. Don't repeat what others have done, just summarize where necessary while quoting correctly: make absolutely sure that you do not plagiarize, knowingly or unknowingly.

Figures should tell the story.

Figures have an immediate message: make it central. Don't let the reader figure out that what really matters is the little glitch in the lower left corner of the curve. Cut out all the information that is not necessary, focus on the message of the figure.
Realize that many readers read a paper like a comic book: they read the figures and captions. So, treat the figures and captions as a storyboard.
The caption, therefore, should also guide the reader. NOT: 'this figure plots A versus B and compares measurements to theory'. BUT: The dependence of A on B, as measured by XXX method, shows that whereas there is good correspondence for low values of B, theory and measurements diverge for large B. Possible causes for this divergence are discussed in section ##'.
If you use figures – or data - from external sources: give proper references. Always.

Length

It is not difficult to fill many pages with text and figures, but we want the report to be concise. It depends a bit on the topic, but 30-40 pages (for graduation projects, 20-30 for internship projects) should be enough, 60 is too long. Keep the main narrative concise and concentrate on the compelling evidence, the results that are needed to support the conclusion. A lot of tables, or measurements, or computer code, or extensive calculations/derivations can go in Annexes. In that way you keep the 'story' compact and compelling, while the technical evidence that should be reported for the sake of completeness is still there.

Do not plagiarize.

You are expected to have this rule bred in your scientific bone, but just to be sure: you cannot use material from others without giving proper reference. Not even half a sentence. Not even a picture that is so basic that there does not seem to be any intellectual ownership associated with it. Not even an anonymous text or figure you have found on the Internet. In fact, you can't use those at all.

If your English is poor, you may be tempted to use some good sentences found in the literature, especially in the introduction, where you have to describe stuff that has been phrased already hundreds of times by others. Don't. It is stealing and we don't steal.

If you want to quote a particularly apt paragraph, simply put it between inverted commas and give the proper reference. There is nothing wrong with a good quote, as long as you give the source.

Make a synopsis or storyboard

The report of an internship, or in particular the graduation project, is likely to be the most complex text you have ever written. Don't underestimate how difficult this is. But there is a method to deal with the complexity, and that is the '**synopsis'**.

In a synopsis you specify every chapter, then every section, then every paragraph of the report: everything but the actual text. You also indicate the approximate length and the figures you intend to use.

'In this section I introduce the experiment, describe the apparatus, the calibration procedure, the accuracy of the measurements. It contains two figures: schematic of the set-up and a typical result. Estimated length: 3 pages of text.'

If you use Word, you should use the '**outline'** function. This allows you to design the entire document in synopsis, set up the structure, the hierarchy of chapters, sections and paragraphs, make sure everything is there, move things around to get the right order etc.

You should discuss this synopsis with your supervisor: once you have agreed on this skeleton, the rest is a filling-out exercise. All the difficult thinking was already done for the synopsis, from there on it is just a matter of producing the lines of text.

Then you should also decide on the figures you are going to use. Plan them early on, produce them and see if they tell the entire story. Make a storyboard. Write the captions.

Plan 1 day per page of report

Once you start the actual writing: count 1 day per finished page of report. That is, assuming that all measurements and calculations and analyses have been done already – so this is the time needed to write, decide on the crucial figures and make them in final form, iterate with your supervisor and do the final lay-out. Make a planning – if you fall short of this pace, you'll need to work harder.

This also tells you how much time you need to reserve for the report writing: for a 40-page report that would be 40 (working) days. Again, that is assuming that all measurements, calculations, analysis etc. have been done and the synopsis has been written.

And don't forget to also count the time for an iteration with your supervisor. They need a week to give you feedback, after which you need a few days to implement.

And finally: the final product must be submitted to the committee at least a 5 working days before the defence (in the case of the Fusion master's). For other programmes this tends to be 10 working days.

Warning: 30-40% of the project time will be needed for reporting

For a typical graduation project of 45 EC (~31 weeks) and report (~40 pages + annexes = 8 weeks writing + 2 weeks feedback + 1 week submission time) this means that the reporting sec (no analysis, no extra measurements or computer runs) typically takes 30% of the

project time. If you count the planning from the end of the prelude even 40%. If you do not plan for this, you will almost certainly run into trouble at the end of the project.

One very good remedy for this: write parts already during the project. The introduction, the 'Chapter 2', the description of the experiment or the code …all of these can be written while you are in the middle of the project. Not only does that save you precious time at the end of the project, but you'll also find it very helpful to fully understand what you are doing when you write the relevant sections of the report. Highly recommended.

Be concise! Apply text compression.

With scientific reports, brevity is called for. There is a 3-step procedure to achieve that.

1. After you have written a text, you go over it paragraph by paragraph and for each you ask 'is there an essential loss of information if I delete the entire paragraph?' If the answer is 'no', delete. You'd be surprised how many paragraphs turn out to be superfluous.
2. After that, you repeat the same procedure with sentences: kick out all sentences that can be missed.
3. And after that, you apply the procedure to words. You'll find that many words, in particular adjectives, can be missed. In fact, the text is much better without them. Especially the words that give an emotional colouring to a text, such as 'very' or 'unfortunately' or …(you fill in your own pet words), are best avoided altogether.

Do try this procedure at home! It hurts, but your text will shrink by 30% while gaining clarity and strength.

2. The main elements of the report.

The overall structure

The report has an introduction at the beginning and a discussion at the end. In between you put everything that is needed for the reader to fully understand what you have done, how you have done it, what the results were, what theory or models you have developed:

- introduction
- [factual account of your work]
- discussion

You have all been trained to write the bit in the middle. It should be factual, concise etc. Results should be strictly separated from interpretation. This is the straightforward part.

The introduction and discussion, however, are the places where you show that you master your subject. This is where you place your work in the larger context, where your phrase your research question and break it down into manageable bits (introduction) and evaluate in how far you have managed to answer that question – and have generated new questions (discussion).

The bit in the middle is ok as long as it is a technically sound, factual and correct description of what you have done. It is literally a report: it does not change any facts.

The introduction and discussion, on the other hand, give a place and meaning to your work. Although these consist of only a few pages, and although writing them takes only a fraction of the time of the project, they are very important for the jury. So do spend enough time on those pages.

The Introduction

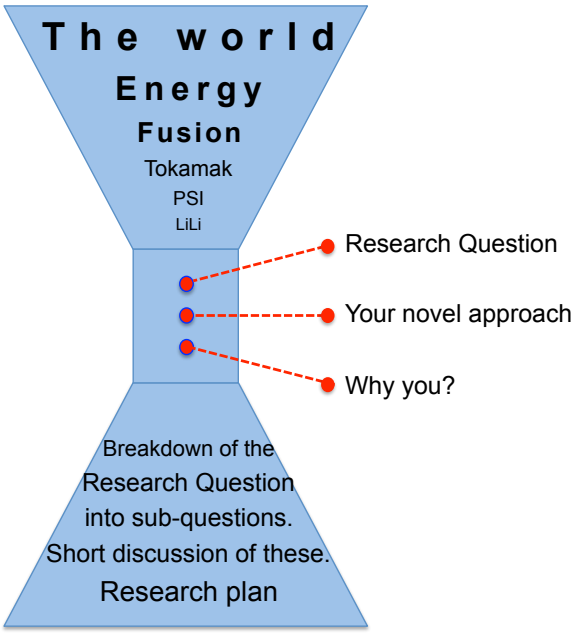
The introduction is important and should be written at the start of the project.

Before all else: in the introduction you define your research question and you give a breakdown of it into logical research steps, which then defines your research plan (and structure of your report). We insist on your writing the introduction right at the beginning of the project. Other people may have told you that you write the introduction after everything else has been written, but we fundamentally disagree. Writing the introduction forces you to think the project through, this is an extremely important phase of the project.

Having said that: in the course of the research new things may come up, or things may turn out to be different than you originally thought, or for various external reasons the research may change course halfway. So the introduction will need revision at the end of the project. But that does not take anything away from the need to write it at the start of the project. It's essential!

Structure of the introduction

The introduction has an hourglass structure. It starts with 'the world' and tapers down to the research topic. In the narrow waist of the hourglass the particular research question for your project is phrased, you outline your original approach and make clear that you are in a good position to do this work. And after that you diverge again by giving a breakdown of the research question in logical and manageable sub-questions.



From 'world' to 'research topic': positioning and motivation

The first part of the introduction starts with 'the world' and tapers down to the specific problem field you want to address. In the case of fusion research the typical line could be:

- Energy/Climate problem
    - fusion as one of the few options (to save the world)
        - open issues in fusion
            - the particular issue you want to focus on, e.g. PSI.
                - a particular approach to this issue, e.g. Liquid Lithium

Be concise. Nobody is waiting for the zillionth extensive treatment of the world energy problem. But this does constitute the motivation for your work. This is the 'why'.

The reader wants to know quickly what the report is about. Therefore, somewhere on the first page we want to see the sentence that starts with:

> 'In this paper we deal with the topic … {e.g. of ELM-induced damage to plasma-facing components and the possible use of liquid metals to mitigate that damage}'

The focal point of the introduction: the Research Question.

Once you have boxed in the research topic, you need to define your specific research question. This is an extremely important step; it defines the entire project. Take time for it and discuss it with your supervisor.

But before you can state your research question, you'll need to say a few words about the state of the art in the chosen topical field and identify what you plan to add to this.

> {'In the literature 3 distinct liquid metal wall concepts are described….(references) … In another paper, on the cooling of milk tanks in dairy industry, a quite different concept has been introduced in a completely different context. We think that this

concept, with suitable adaptations, could be applied to the design of an essentially new, i.e. 4th, liquid metal wall concept for fusion applications'}. (just making this up)

So now you have described the place of your work in the world and shown its relevance, defined the field in which your research falls, described which particular item in that field you want to address and indicated that you have an original idea that will enrich the literature on the topic. You have the full attention of the reader.

At this point you want to develop your theme of choice by briefly discussing the main scientific/engineering issues.

> 'In order to address the feasibility of this new approach, we have to consider the following issues {heat load, melting point, capillary forces, ….}.'

After that the reader is in the picture, understands the issues, understands how your approach is different from what has been done in the literature. Now is the time to actually phrase your research question:

> 'Research question: assess the feasibility of a plasma-facing component for a fusion reactor based on the concept of a flowing, double-layer liquid metal sheath, capable of taking a steady heat load of 10 MW/m^2 as well as ELM-induced peak heat loads of 1 GW/m^2 during 1 ms pulses.'
>
> (just making this up again)

The research question must be phrased in such a way that it can realistically be answered, and it should not be vague. 'Carry out a detailed study of turbulence in a hot plasma', for instance, is way too vague: it does not specify what you want to get out.

This is the central point in the introduction, the narrow waist of the hourglass. Up to here you have been narrowing down the field to your specific question, from here on you are going to expand: develop the question into a research plan. But before you do that, the reader needs to have two bits of information:

- **What is your original idea?** If you have not already introduced how you plan to give a new contribution to the field, you'll need to do it here.
- **Why you?** The reader will now ask: ok, so the topic is interesting and important, the research question is well-phrased and sufficiently precise, the author has an original approach … all very well, but is he/she actually in a position to carry out this project?

You may have a wonderful research question concerning the inside of Mars, and a very original idea on how to go about it, but how on earth are you going to make that happen..

This may seem obvious, but you have to very briefly indicate this:

- you will carry out the project in e.g. the Princeton fusion lab (so the reader knows: the environment is ok)
- and you will use the COMSOL software package to which you have access through the TU/e
- and you will have your radioactive samples analysed at NRG Petten

At this point all conditions for success are there. Now the reader is willing to read more about your research plan. Time for the diverging part of the hourglass.

Next, you realize that to answer your research question you'll need to undertake several actions. For instance:

- lay down the basic design and the parameters that define it;

- set up the theoretical framework that is needed to do your analysis;
- build a set-up in which you can investigate prototypes experimentally;
- design a test protocol that will result in data that will answer your question;
- build a computational model.

In this way you break the research question up in a few manageable blocks. This will define your research plan and will also lay out the structure of your report. Basically, every sub-question translates into a chapter. Normally there is a logical order in which to take on the sub-questions, so this is also the basis for a planning as well as the order of the chapters in the report.

'Chapter 2': review of literature, description of experimental facilities etc.

Now you have basically defined your project by breaking down your research question into subquestions, and with that you have also defined the structure of your thesis. However, before you start with the description of your own work (i.e. the experiment you set up, the code you wrote, the new theory you developed…) you need to lay down the foundations. This is done in a separate chapter – usually chapter 2, i.e. directly after the introduction. This is where you collect the 'known' information that the reader should have in order to understand your work. This typically comprises for instance:

- a concise summary of the relevant literature; the formulas from literature that you are going to use
- an overall description of the experimental facility that you are going to use: e.g. the Magnum-PSI device, or the W7-X stellarator
- a description of computer codes that you are going to use (i.e. use, not write), such as the JOREK code.

The challenge is to keep 'Chapter 2' as short as possible, while giving proper due to the work of others you build your work on. Don't repeat derivations of formulas, but do give the formulas (with proper referencing, of course), say what they mean (and explain all symbols) and specify the conditions in which they can be used.

Make sure to put everything that is not your own work in Chapter 2. In that way the reader knows exactly where 'background' stops and your work starts. Conversely: do NOT use Chapter 2 to report original work of your own. If you quote two papers that give useful formulas, that is fine. But if you combine those formulas in a way that nobody else has done, to produce a new formula that is useful – then that is your new contribution and that should go elsewhere in the report.

The central chapters.

As said, the middle bit of the report ideally is straightforward. It contains chapters such as 'experimental setup', or 'results'. We assume that you have all been taught how to write these chapters. Therefore, we will not expand on them here.

Summary, Abstract, Conclusion, Discussion: what is what?

There is often confusion about the functions these important sections.

The **abstract** is normally placed in front of the article. It is short, but should contain the essential results (when applicable: numbers, with error bars). A quick reader who scans the abstract should not miss anything of importance. It focuses on results and should not

repeat the introduction. Here is a link to a useful instruction on how to write a good abstract: https://urc.ucdavis.edu/how-write-abstract.

The **summary** comes towards the end of the paper, and its length should be commensurate with the length and complexity of the paper. Especially in a long paper, with several different experiments, it is useful to bring everything together in a summary. In short paper the summary is often only one or two lines.

The summary is often combined with the discussion: 'In summary, these are our findings….'. And then you continue with a discussion. That would make a chapter '**Summary and discussion'.**

Very important: the summary should not contain anything that was not presented in the paper: no new data, no new results. Just summing everything up that was scattered in the report.

The **discussion** is a very important part of your report. As said before, this is where you show your academic prowess. In the discussion you do the following:

- You place your results in the **context of the literature**. If others have measured the same thing you must compare your results with theirs and discuss why they differ; if others have dealt with the same problem you must explain how your method is different, compare the results and comment on differences. Etc. Here you show that you have made a proper study of the relevant literature and that you are aware of what others have done.
- You discuss the **loose ends** in your own work. Yes, there are always loose ends. These tend to bother the beginning scientist – you probably want to deliver the package neatly wrapped up. But loose ends are inevitable. Don't hide them, deal with them professionally. If you have made assumptions: comment on what happens if the assumptions don't hold. If the measurements showed some unexpected results that did not fit in the present study: this is the place to come back to those and comment on them.
- Outlook: after having concluded the project you normally are full of ideas how it could have been done better with the knowledge of now, and you have ideas for further research – new ideas, or just bits that you did not have the time to do or that couldn't be done in your project because the apparatus was broken, or you did not have enough machine time. Or your newly developed theoretical insights call for a new experimental verification. Anything at all: at the end of your project you are the world-leading specialist on the particular topic and we want to benefit from your insights.
- Impact, the helicopter view: Very importantly, in the discussion you return to the research question, evaluate if you have answered it and what the answer was. And after that, you contemplate the meaning of the results. You trace back the hourglass, as it were. You did your research to answer a question that was part of a research area that was part of an issue in fusion energy that was a future energy option that was needed to save the world…..So somehow, your work has an impact beyond the direct question you tried to answer, and it is important that you give some proper, realistic, thought to that impact.

The **conclusion** should be exactly what the word says: it concludes the report. The main result in short. Keep it brief – you don't want too much overlap with the abstract. A few lines is usually all that is needed.

3. Figures – technical requirements

We have already said that figures are very important in a scientific paper. So they should be of good quality:

- Try to make all your figures in a consistent style: same type of axis, same line weight, same fonts, same colour scheme.
- The font size in the figure should be comparable to the font in the written text. That would typically be 10-12 pt.
- Make sure that all lines and symbols are distinguishable and defined in the caption
- Importantly: remove all information that is not necessary for your report.
- If you use a figure from an external source: give proper reference. And: you cannot just copy it – that would be an infringement of the copyright. In that case you need written consent from the author or publisher. Alternatively, you can basically redo the figure (several ways to do that – it usually takes not too much time with modern tools). Then the copyright does not apply anymore – but the intellectual property of course still resides with the original author, so you always must give proper reference.