

# NTNU Laboratory Report Template

For Physics Reports

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## Abstract

The abstract should be *very* brief, two or three sentences may be enough. It must answer the following questions, however: 1. What did you do (What did you measure)? 2. How did you do it (which method)? 3. What did you discover (what was the results of the experiment)? Results in form of numbers should be accompanied by an error:  $R = (3.05 \pm 0.02) \cdot 10^{-6} \text{ kg/s}^2$

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**Figure 1:** Example image in png format, taken by yours truly.

## 1. Introduction

The introduction is the most important part of any paper or report. This is where you risk losing the reader. Give motivation for what you are doing; why is it interesting? Why should anyone care? What problems do you hope to solve through this experiment? Set the stage for your story: if the introduction lacks motivation, few readers will continue on to the next section. You can also provide historical context if this is relevant/ useful.

### 1.1. Problem Description

Consider using dividing the introduction and other sections of the report into different parts using `\subsection`. This will make the report more reader friendly.

## 2. Theory

If the theory section is short, you may combine it with the introduction or method section.

This section should provide a short overview of the theoretical background for the experiment.

Include all equations (but not elementary/ trivial equations that one can assume the reader knows) that are used in the report. Do not reference the experiment in this section. Rather, write more general and use arbitrary variables in equations (not specific variables for the experiment).

Here are some equations:

$$\begin{aligned} \nabla^2 V &= 0 \\ \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} &= 0 \end{aligned} \quad (1)$$

Equation (1) is Laplace's equation for electric potentials in two dimensions [1, pp. 131, 136].

Here is an example of an equation with different cases:

$$\int_0^a \sin(nx) \sin(n'x) dx = \begin{cases} 0, & \text{if } n' \neq n \\ \frac{a}{2}, & \text{if } n' = n \end{cases} \quad 1$$

The `NTNU-lab.sty` includes a some spicy equal signs. For example:

$$\mathbf{E} \stackrel{\text{def}}{=} \frac{\mathbf{F}}{q} \quad (2)$$

$$\mathbf{E} := \frac{\mathbf{F}}{q} \quad (3)$$

$$a \stackrel{?}{=} b \quad (4)$$

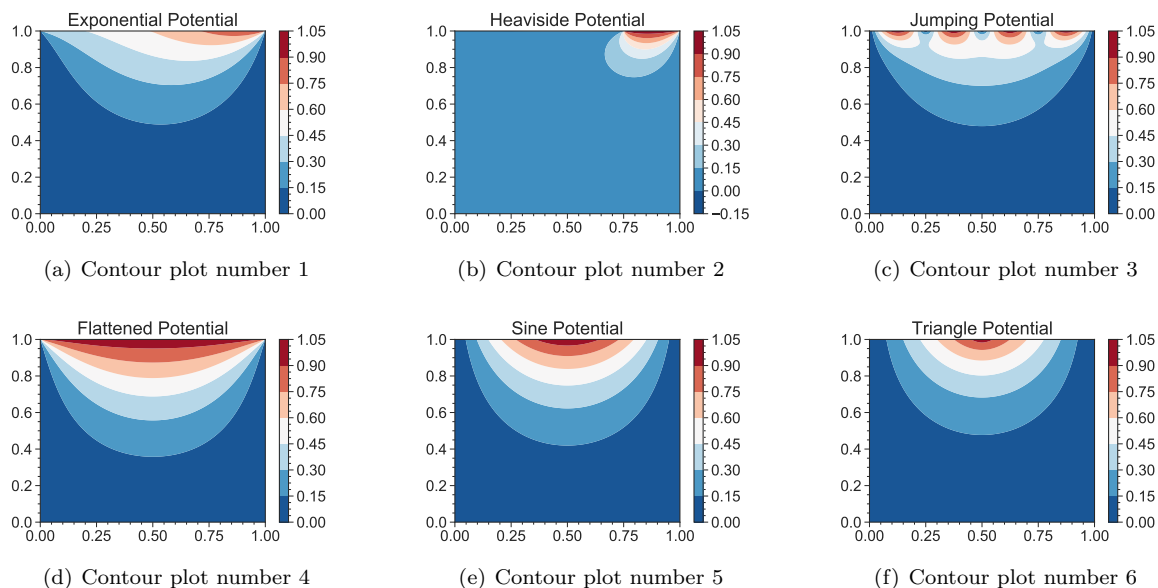
$$G \stackrel{\text{m}}{=} 6.6 \cdot 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2} \quad (5)$$

The equality symbols in eqs. (2) and (3) means equal to by definition. Note that these may sometimes be used slightly different from  $\stackrel{\triangle}{=}$  (equal to by definition):

$$a := 3, \quad \Rightarrow \quad a + 2 \stackrel{\triangle}{=} 3 + 2 = 5$$

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<sup>1</sup>Notice that the differential operator is *not* italic and that there is a tiny space in front of it.



**Figure 2:** Contour plots for different potentials  $V_0(x)$ , along the line  $y = 1$

The symbol in eq. (4) conveys an uncertainty in the statement, as in “We do not know if  $a = b$ , but we think it does.” Such a statement would be followed up by investigating the claim either mathematically or empirically. For example, a paper investigating Ohm’s law could state the hypothesis  $V \stackrel{?}{=} I \cdot R$  at the start of the paper.

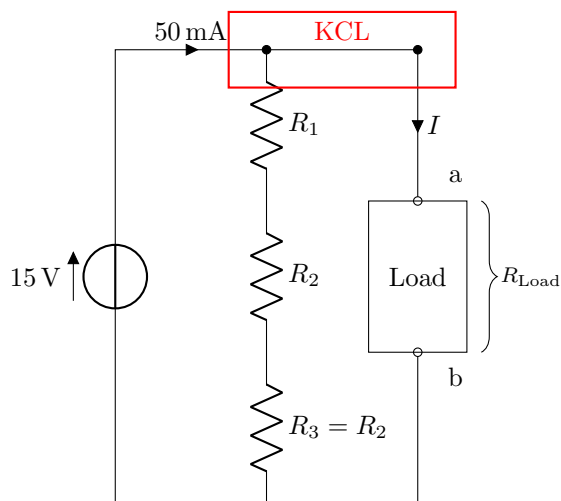
The symbol in eq. (5) is called “measured by”. Sadly I’m not familiar with how this symbol is used. I can, however, think of two possibilities:

- to define a mathematical object<sup>2</sup> by measurement(s) (similar to  $\stackrel{\text{def}}{=}$ )
- to specify the measured value of a mathematical object.

An example of the first usage would be the gravitational constant, which numerical definition relies on measurements:  $G \stackrel{\text{m}}{=} (6.674\,30 \pm 0.000\,15) \cdot 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$ . [2]

To give an example of the second way to use the symbol, let us assume you measured a current  $I_1$  to be  $(3.3 \pm 0.1) \text{ A}$ . Then, you would simply write  $I_1 \stackrel{\text{m}}{=} (3.3 \pm 0.1) \text{ A}$ , and it would imply that this value was measured (without the need to explicitly mention this in the text).

Personally, I would chose the latter way of using the symbol, simply because this way of using it would occur more frequently in undergraduate



**Figure 3:** A circuit diagram. We can apply Kirchhoff’s current law (KCL) in the red box and Ohm’s law to figure out the unknown values.

<sup>2</sup>I used this word as an umbrella term for variables, constants, vectors, tensors and other things that can be measured/ found empirically.

reports than the former. If you chose to use this symbol, I would recommend clarifying how you use it in a footnote. That is, if its meaning is unclear and/or ambiguous given the context.

Figure 3 shows a circuit diagram drawn using `circuitikz`. Table 1 shows possible values for the circuit and is an example of a table with a coloured row. It also shows an example of using footnotes inside tables (normal footnotes inside tables will not be displayed).

$R_{\text{Load}}$ ( $\Omega$ )	$I$ (mA)	$R_1 + R_2 + R_3$ <sup>3</sup> ( $\Omega$ )
350	42.9	2100
400	37.5	1200
500	30	750
1000	15	428.6
1300	11.5	390

**Table 1:** Some values for the circuit in fig. 3.

### 3. Method and Equipment

An important quality of a scientific report is that it should be possible to redo the experiment based on the information found in the report. However, this does not mean that you should write every detail. Only include parts necessary to obtain the final result. Specific details like serial numbers, manufacturer, etc. goes in your lab journal, an appendix, or can be mentioned briefly if it is relevant to the discussion. Remember that a scientific report should be short.

Remember to use helpful figures and refer to them. In fig. 2 you can see examples of vector graphics images.

You can also mention *noteworthy* safety measures you took during the experiment in this section of the report.

### 4. Results

The results section can be combined with the discussion if appropriate. In case of many sub-experiments where the results are vaguely related or unrelated, it would be appropriate to combine the results and discussion. This way you have the information related to each sub-experiment gathered in one place.

Provide uncertainties for the results, but don't discuss it. Do not involve personal opinions, just present the cold hard results in form of numbers, tables, graphs and some sentences.

Table 2 shows a nice table with comma alignment.

**Table 2:** Table with comma alignment.

$m$ (kg)	$a$ ( $\text{m s}^{-2}$ )	$F$ (N)
1.2	10.1	12
2.44	6.92	16.88
10	1.0	10
8.2	1.1	9.0
100	1	100

### 5. Discussion

You should try to show insight into what happened and why, and how things could have gone differently. If you have presented any background theory, try to tie it together with your results. How do they relate? If they differ, try to explain why. Even if things didn't work out as intended, a good discussion shows that you've understood what went wrong and how you could potentially overcome these obstacles.

### 6. Conclusion

The conclusion should summarise your main results and main points from the discussion. A rule of thumb is to not present any new information (information not found in the results or discussion).

### Acknowledgements

Acknowledgements (nb. takksigelser, nn. takkseingar) is not a requirement in a laboratory report. However, it is used in most scientific articles. It looks more professional and adds some "extra spice" to your report. Here is an example:

The authors would like to thank Dr. Ola Normann at the University of Oslo for assistance with the SIMS-analysis and Dr. Kari Normann at NTNU for fruitful discussions and support concerning melt spinning of silicon. This work was financially supported by the Norwegian research council and the Norwegian PhD Network on Nanotechnology for Microsystems.

### References

- <sup>1</sup>D. J. Griffiths, *Introduction to electrodynamics*, Fourth edition (Cambridge University Press, 2017), ISBN: 9781108420419.
- <sup>2</sup>*Newtonian constant of gravitation, G*, The NIST referanse on Constants, Units and Uncertainty, <https://physics.nist.gov/cgi-bin/cuu/Value?bg> (visited on 04/21/2022).

<sup>3</sup>This is the same as  $2R_1 + R_2$

## Appendix A. Additional Information

You can use the appendix to include information that is relevant, but does not belong in the report. In most cases however, the appendix can be omitted and isn't necessary.

### Appendix A.1. Python code

If you used python code to process data, you can include the code (or a shorter version of it) in the appendix. Usually, however, it is better to hand in a separate file containing your code together with the report. <sup>i</sup>

Below is a simple example of some code used to calculate the values for the circuit in fig. 3 on page 2 <sup>ii</sup> found in table 1:

```
def Find_circuit_vals(R_load):
    # Function to calculate values of
    # circuit
    V_s=15 # Voltage from source
    I_i=50 # Initial current before
    # branching
    I_load=(V_s/(R_load))*1000
    I_2=I_i-I_load
    R_other=V_s/(I_2/1000)
    return I_load,I_2,R_other
```

Listing 1: Example from external file

The code from listing 1 was displayed using a .py file. Since the lines are not numbered in this code example, you can copy and paste the code from the PDF into python without many issues (does however need to correct indents).

I would advice against using the `lstlisting` package to display code, as this introduces many unnecessary problems when trying to copy-paste the code.

## Appendix B. Appendix footnotes

This template has a separate roman numeral footnote system for the appendix. You can chose to use this or normal footnotes in the appendix. Use the command `\appendixfootnote{text}`<sup>iii</sup> to get a (lower case) roman numerical footnote. I added this footnote system because I thought it would be nice to have a separate footnote system for the appendix, since this section is in some ways separate from the rest of the document.

<sup>i</sup>Rule of thumb: short code goes in the appendix, long code goes in a separate file

<sup>ii</sup>exaple usage of the varioref package

<sup>iii</sup>Note that there is `no` commands: `\appendixfootnotemark` and `\appendixfootnotetext`

## Appendix C. Boxes

This template also include two box environments to highlight text. I will showcase these in the two next subsections.

### Appendix C.1. Info Box

The first environment is named `infobox` and is numbered, which allows for references to the box. You can also change the title of the box as well as the colours. To change the colour use the command `\SetInfoBoxBgColor{}` (changes background colour) and `\SetInfoBoxFrameColor{NTNU_blue}` (changes frame colour). The default colours are a light blue background and a darker blue frame. Here is an example:

InfoboxAppendix C-1

Here is an infobox. You can also write math inside it:

$$3x + 5y = 6z^2$$

Here is a reference to the infobox: box `Appendix C-1`. Notice that the structure of the infobox numbering is (section number)-(box number). The first infobox in section 2 thus has the reference 2-1.

### Appendix C.2. Simple Box

The second environment is just a coloured box with no number or title. This can be used just to highlight text.

I also added a theorem environment `Sclaw` that may prove useful.

**Scientific law 1 (Newton's 2. law).**

$$\vec{F} = \frac{d\vec{p}}{dt}$$

You can reference the theorem environment: See scientific law 1. I also added a Norwegian version of the environment: `naturlov`. Let us change the colour of the next box to blue using `\SetSimpleBoxColor{bg_blue}`.

To create your own theorem environment, use the command `\newtheorem{}{}[]`.

You must use the `newtheorem` command before `\begin{document}` (the preamble). You can read more about the theorem environment in the [Overleaf documentation](https://www.overleaf.com/learn/latex/Theorems_and_proofs) using this link: [https://www.overleaf.com/learn/latex/Theorems\\_and\\_proofs](https://www.overleaf.com/learn/latex/Theorems_and_proofs).