



UNIVERSITY COLLEGE LONDON

DEPARTMENT OF SILLY WALKS

MY THESIS TITLE

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Submitted in partial fulfilment for the degree of **Doctor of Philosophy**

January 22, 2019

I, JOE BLOGGS, confirm that the work presented in this report is my own.
Where information has been derived from other sources, I confirm that this has
been indicated in the report.

Signature

January 22, 2019

Date

Abstract

My research is about stuff.

It begins with a study of some stuff, and then some other stuff and things.

There is a 300-word limit on your abstract.

Impact Statement

UCL theses now have to include an impact statement. (*I think for REF reasons?*)

The following text is the description from the guide linked from the formatting and submission website of what that involves. (Link to the guide: <http://www.grad.ucl.ac.uk/essinfo/docs/Impact-Statement-Guidance-Notes-for-Research-Students-and-Supervisors.pdf>)

The statement should describe, in no more than 500 words, how the expertise, knowledge, analysis, discovery or insight presented in your thesis could be put to a beneficial use. Consider benefits both inside and outside academia and the ways in which these benefits could be brought about.

The benefits inside academia could be to the discipline and future scholarship, research methods or methodology, the curriculum; they might be within your research area and potentially within other research areas.

The benefits outside academia could occur to commercial activity, social enterprise, professional practice, clinical use, public health, public policy design, public service delivery, laws, public discourse, culture, the quality of the environment or quality of life.

The impact could occur locally, regionally, nationally or internationally, to individuals, communities or organisations and could be immediate or occur incrementally, in the context of a broader field of research, over many years, decades or longer.

Impact could be brought about through disseminating outputs (either in scholarly journals or elsewhere such as specialist or mainstream media), education, public engagement, translational research, commercial and social enterprise activity, engaging with public policy makers and public service delivery practitioners, influencing ministers, collaborating with academics and non-academics etc.

Further information including a searchable list of hundreds of examples of UCL impact outside of academia please see <https://www.ucl.ac.uk/impact/>. For thousands more examples, please see <http://results.ref.ac.uk/Results/SelectUoa>.

Acknowledgements

Acknowledge all the things!

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List of Symbols

The next list describes several symbols that will be later used within the body of the document. If not using `latexmk`, will need to run code `makeindex Main.nlo -s nomencl.ist -o Main.nls`. In any case, compile twice

\hbar Reduced Planck constant

c Speed of light in a vacuum inertial frame

Chapter 1

Introductory Material

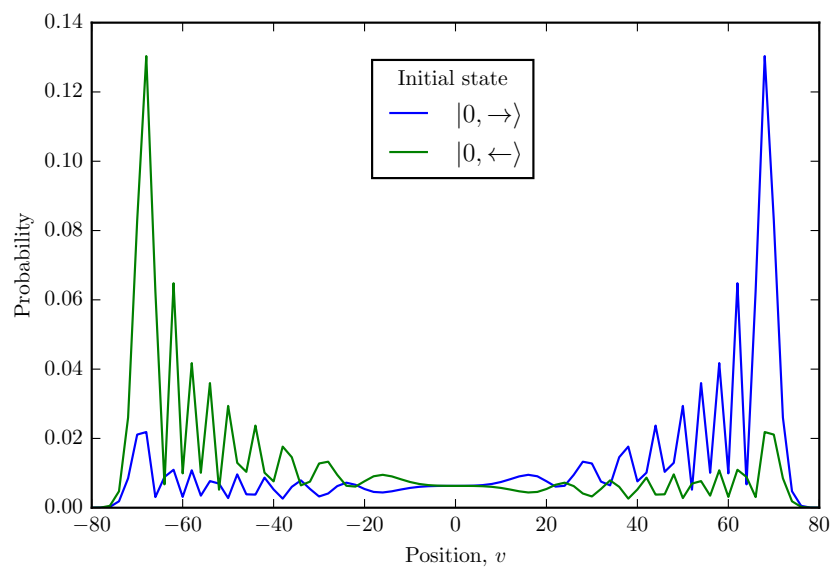


Figure 1.1: A sample figure.

Table 1.1: A sample table

Table 1.1: A sample table

1.1 A section

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Chapter 2

My First Content Chapter

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$$\bar{x} = \frac{1}{n} \sum_{i=1}^{i=n} x_i = \frac{x_1 + x_2 + \dots + x_n}{n}$$

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$$\int_0^\infty e^{-\alpha x^2} dx = \frac{1}{2} \sqrt{\int_{-\infty}^\infty e^{-\alpha x^2} dx} \int_{-\infty}^\infty e^{-\alpha y^2} dy = \frac{1}{2} \sqrt{\frac{\pi}{\alpha}}$$

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$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial y^2} + \frac{\partial^2 \Phi}{\partial z^2} = \frac{1}{c^2} \frac{\partial^2 \Phi}{\partial t^2}$$

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Chapter 3

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Chapter 4

General Conclusions

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Appendix A

An Appendix About Stuff

(stuff)

Appendix B

Another Appendix About Things

(things)

Appendix C

Colophon

This is a description of the tools you used to make your thesis. It helps people make future documents, reminds you, and looks good.

(example) This document was set in the Latin Modern typeface using L^AT_EX and BibT_EX, composed with a text editor.

Bibliography

- [dW18] R. de Wolf. *Quantum Learning Theory* (2018). *Quantum Information Processing* 2018, URL https://qutech.nl/wp-content/uploads/2018/01/QIP18MLtutorial_Ronald-de-Wolf.pdf.
- [FN18] E. Farhi and H. Neven. *Classification with Quantum Neural Networks on Near Term Processors* (2018). [arXiv:1802.06002](https://arxiv.org/abs/1802.06002).
- [Han16] S. Hanneke. *The Optimal Sample Complexity of PAC Learning*. *J. Mach. Learn. Res.*, **17**, 1319 (2016).
- [NC11] M. A. Nielsen and I. L. Chuang. *Quantum Computation and Quantum Information: 10th Anniversary Edition*. Cambridge University Press (2011).
- [NV00] A. Nayak and A. Vishwanath. *Quantum Walk on the Line* (2000). [arXiv:quant-ph/0010117](https://arxiv.org/abs/quant-ph/0010117).
- [Val84] L. G. Valiant. *A Theory of the Learnable*. *Commun. ACM*, **27**, 1134 (1984).
- [Wat18] J. Watrous. *The Theory of Quantum Information*. Cambridge University Press (2018).

Index

In this index we use the `imakeidx` package. Put `\index{thing}` in whenever “thing” crops up.

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