On the zero-point energy of elliptic-cylindrical and spheroidal boundaries

A thesis presented in partial
fulfilment of the requirements
for the degree of

Doctor of Philosophy
in Theoretical Physics

at Massey University
New Zealand

Adrian Robert Kitson

2009

Abstract

Zero-point energy is the energy of the vacuum. Disturbing the vacuum results in a change in the zero-point energy. In 1948, Casimir considered the change in the zero-point energy when the vacuum is disturbed by two parallel metal plates. The plates disturb the vacuum by restricting the quantum fluctuations of the electromagnetic field. Casimir found that the change in the zero-point energy implies that the plates are attracted to each other. With the recent advances made in the experimental verification of this remarkable result, theoretical interest has been rekindled. In addition to the original parallel plate configuration, several other boundaries have been studied. In this thesis, two novel boundaries are considered: elliptic-cylindrical and spheroidal. The results for these boundaries lead to the conjecture that zero-point energy does not change for small deformations of the boundary that preserve volume. Assuming the conjecture, it is shown that zero-point energy plays a stabilizing role in quantum chromodynamics, the leading theory of the strong interaction.

Acknowledgments

I would like to thank my supervisor Tony Signal for suggesting the topic, giving me the freedom to explore, but always being there when I needed help. Tony, without your support and patience when times were hard, this thesis simply would not exist. Thank you!

The work on elliptical cylinders was done in collaboration with August Romeo, whom I sincerely thank.

Special thanks go to Kim Milton and Bruce van Brunt for helping me more than they probably realize.

The figures of lattice simulations in the chapter on quantum chromodynamics are used with kind permission from Derek Leinweber.

Massey University, the Institute of Fundamental Sciences and the Royal Society of New Zealand are all gratefully acknowledged for financial assistance.

Perhaps I should have included my dad in the previous list? But, dad, I hope you know you mean more to me than just helping pay the bills! To the rest of my family: thank you for listening to me go on about maths and physics... and pretending to be interested.

Finally, I would like to thank all my friends, especially Bill, Warwick, G and Clare.

I dedicate this thesis to my daughter, Delta.

Table of contents

List of figures

Nomenclature

In this thesis, Dirac's constant $\hbar$ and the speed of light c are both unity. The signature of the Minkowski metric is taken to be $(1,-1,-1,-1)$.