Benjamin N. Lovitz
Statement of Purpose

The day of my birth, doctors had trouble reading my vital signs and were forced to use an internal fetal monitor, which they screwed directly into my very malleable dome. This traumatic experience probably explains why I was such a quiet child, and all that solitary thinking inevitably led me to develop a passion for philosophy.

I carried these philosophical leanings through my youth and into my freshman year at Bates, when an introductory modern physics course opened my eyes to a few of the unbelievable and even seemingly paradoxical discoveries in physics. I caught my first glimpses of special relativity and the wave-particle duality of light and matter. I marveled at how bizarre, complex, and yet wholly self consistent these stories were. In subsequent years the stories became more rigorous and revealing. I began to realize these stories comprise physics' own philosophy which is built on empirical evidence and mathematical reasoning alone. I came to Bates an aspiring philosopher, and in four years I have found my philosophy and my purpose in physics. As such, I plan to spend my graduate studies and career writing my own chapter in the physical account of nature.

I am driven to learn and discover new physics, but teaching others what I already know also excites me. I enjoy teaching because it deepens my own understanding and allows me to show my students why I find this field fascinating. The summer after my sophomore year I tutored high school math and physics students full time through two tutoring centers in Portland, Oregon. I have also tutored Bates math and physics students privately during most of my college career.

I find learning and teaching physics compelling in its own right, but it has also provided me the tools to begin my chapter in research. Over the winter semester last year I studied the structure of generalized symmetric spaces of the special linear group $SL_2(\mathbb{F}_q)$ with Dr. Catherine Buell under a grant from the Bates Mathematics Department. I was drawn to the topic by its potential applications in Lie theory and quantum mechanics.

We used Maple software to study the orbit structures of the double cosets induced on $SL_2(\mathbb{F}_q)$, which falls in the spheres of Abstract Algebra and Number Theory. We found patterns in the orbit structures in aims of decomposing them. This research relied heavily on inductive reasoning based on the patterns produced in the Maple output. I reveled in my first experience delving into a mathematical problem in depth with a collaborator. I valued learning how to express my own thoughts and understand Dr. Buell's in a mathematical setting.

At the close of the academic year I was awarded the Bates Rawlings Grant to participate in the Potsdam, NY Mathematics REU May 28-July 22. I studied quantum walks under Dr. Christino Tamon. Our work is pending publication in a combinatorics journal (arXiv:1409.5840). This research fostered my interest in mathematical physics, quantum systems, and quantum computing.

A continuous-time quantum walk on a graph $G = (V,E)$ is given by the unitary matrix $U_G(t) = e^{-itX(G)}$, where $X(G)$ is either the adjacency matrix (XY model) or Laplacian matrix (XYZ model) representation of G. The latter is also known as the isotropic Heisenberg model. We say that G exhibits *perfect state transfer* between vertices $a,b \in V$ at time t if $|U_G(t)_{a,b}| = 1$. These notions have been studied in the context of developing efficient quantum algorithms and also in simulating universal quantum computation.

This research consisted of computational, spectral, and combinatorial algebraic graph theory. We computed quantum walks in Matlab and Sage to determine whether a graph exhibited perfect state transfer. Using the output as a guide we generalized examples of perfect state transfer to infinite families of graphs through spectral and combinatorial analysis of the graphs' matrix representations.

Quantum walks were presented to us as a mathematical physics problem. However, as my Introductory Quantum Mechanics course progressed this semester, so did my understanding of the quantum spin chains which motivate quantum walks. With this understanding I have come to realize the incredible physical implications of some results we studied. In particular, Godsil et al (2012) proved that a quantum walk between the two end vertices of a path comes arbitrarily close to perfect state transfer precisely when the number of vertices satisfies one of three number theoretic conditions, two of which are linear functions of an arbitrary prime. This groundbreaking connection between primality and quantum spin systems leaves me awestruck. Results such as this, along with my incredible experience in the Potsdam REU, make me eager for more research with ties to quantum computing.

At the close of the REU I was awarded a travel grant from the Mathematical Association of America to give a talk on our research at Mathfest 2014 August 6-9 in Portland, Oregon. After Mathfest I flew to Bates to learn the method and theory behind Dr. Nathan Lundblad's BEC apparatus in preparation for my thesis. I developed an understanding of the traps, slowers, and the condensate itself, which deepened as my quantum mechanics course progressed this fall. I marvel in the BEC's ability to display quantum phenomena on a macroscopic scale, as well the potential uses in quantum computing.

For my thesis I am studying optical frequency doubling using a nonlinear crystal in a bowtie mirror configuration. The motivation for this project is to use the doubled light in Dr. Lundblad's BEC apparatus for faster adiabatic loading of the condensate into an optical lattice, as described in a recent theoretical proposal set forth by Masuda et al (2014) for a "shortcut to adiabaticity." Thus far we have built a Michelson interferometer to characterize a diode laser system, and have used the interferometer to develop an understanding of the relevant piezoelectric control mechanisms for use in the resonant cavity. In the winter we plan to obtain a doubling crystal and begin studies of the doubling process itself with a Ti:sapphire laser system.

This thesis has provided me a small taste of experimental physics to complement a backdrop of theoretical research. I have enjoyed exploring the novel methods and mindset required for experiment, but I still consider myself an aspiring theoretician.