Introduction

Over the summer, I spent six weeks with Vlatko Vedral’s Frontier’s of Quantum Information Research group in the physics department at the university of Oxford. This group focuses on the intersection between quantum information and thermodynamics; this was one of the reasons I pursued a summer project in this group as their research interests aligned well with the content I had been studying that year (quantum mechanics, thermodynamics and statistical mechanics amongst other things).

Project Outline

My project was to look into a specific ‘quantum Maxwell’s demon’ thought experiment in which the familiar particle in a box setup of the Maxwell’s demon thought experiment is replaced with a single photon in a box. The choice of a photon meant that quantum considerations had to be made and it was chosen that we would consider only one photon so as to make the setup as simple as possible. We did this because we were interested in looking at the entropy of the system as it evolves With more complex systems comes an increase in entropy from coarse graining, therefore the aim was to set up the experiment such that any (or as much as possible) entropy detected would be fundamental.

How I went about it

I went about the project by, firstly setting up the experiment with the photon in the box modelled as a simple harmonic oscillator. The insertion of a division in the centre of the box as per the original Maxwell’s demon experiment was modelled as the introduction of a potential barrier into the box; this changed the wavefunction of the photon. We then needed to take a measurement of which side of the division the photon was; this was difficult because quantum measurement is a destructive process and for the functioning of the Maxwell’s demon setup, we require that we do not destroy the photon (we need it to remain to exert a pressure on the partition/potential barrier). One way we tried to get around this was to consider the photon being absorbed and then reemitted by the walls of the box. However, there would be an energy loss for the photon in this process, therefore we would need the box connected to some energy reservoir to give the photon the remaining energy it needs to match the original absorbed photon.

My Routine

When I secured this project, it was planned that I would have a desk within Vlatko’s group so I could experience the group dynamic, have multiple researchers and graduate students to ask questions to and experience other aspects of working in a research group e.g. group meetings. However, because of the Covid-19 pandemic, this was not possible and so I conducted the entire project from my home in Coventry. My contact to the group was through skype calls with Vlatko on a roughly weekly basis; I found this one of the more challenging parts as I was faced with a lot of new material and think I would have benefitted from being surrounded by more people to whom I could ask questions. I was invited (and am still invited to) virtual weekly group meetings; I have found these a great way to see the research done by the group members and get an insight into how a theoretical physics research group functions. The pandemic also disrupted my summer project in the sense that my exams were moved to the start of my third year and so the project was not my sole focus at the time because I was also balancing revision.

Results

Unsurprisingly I, as a second-year undergraduate physical student, did not make any major breakthroughs in quantum information theory. However, I did learn a lot in many areas of quantum physics, information theory and thermodynamics. I also gained the valuable experience of what it is like to work in a physics research group which has helped me decide what I’d like to do and plan for my future.

I am very grateful to Vlatko Vedral and his group for allowing me to join them for six weeks and to the Rokos fund for allowing me to have this opportunity.