Dear Admission Committee:

"Factoring large numbers is tough!". I have heard that many times. But I remember very well the first time I did. I was training for the math olympiads in high school. It was a number theory lecture, and we were learning about Fermat's theorem. "The best computer could attempt it for years without any chance of success". It was really surprising for me. I learned to factor numbers in middle school, how could it be so hard? My math olympiads years left me many more memories and lessons, and I was very fortunate to participate in the International Mathematical Olympiad in Amsterdam. But that single phrase really got stuck in my head. Many years later, I found out that a quantum algorithm could factorize large numbers in a reasonable amount of time. And just like that, one of my childhood beliefs was shattered. I had to learn about this algorithm!.

By that time I was in the middle of my undergraduate studies in Physics and Mathematics at Universidad de Los Andes, the most prominent university in Colombia. The following years, quantum computing became my greatest interest. I started with Nielsen and Chuang's book, reading about quantum algorithms and quantum information. Enrolling in seminars and congresses on the topic, I even got to understand Shor's algorithm. Eventually, I had a breakthrough. It was in a fascinating lecture by Andrei Bernevig at my university where he presented a solution to one of the biggest challenges in quantum computing: high-decoherence. To address it, he proposed using Majorana quasiparticles appearing at the edges of topological superconductors. It was brilliant. Somehow topology seemed to trivially fix the decoherence-problem. Then they just needed to braid these Majoranas to encode the information and create quantum algorithms. Eureka.

This nice idea receives the name of topological quantum computing. I spent the rest of my undergraduate researching this field and wrote two theses projects. While my thesis in physics was centered on the main problems around Majorana fermions and topological materials, in my mathematics thesis I used an algebraic approach to understand topological quantum algorithms. These two projects boosted my abilities by solving numerical problems, using advanced mathematical tools, and then applying them to physics. Furthermore, the combination of approaches gave me a more comprehensive background on the topic. In particular, I learned that this "braiding" process was far more difficult than it seemed in Bernevig's lectures. But still, the idea was beautiful, the experiments were promising, the field was hot, and it was applicable to quantum computing. I was really looking forward to continue working on this topic. I found that opportunity at the University of São Paulo, consistently ranked as the best university in Latin America.

During the last two years, I have been in São Paulo pursuing a thesis-based masters degree. My advisor is Prof. Luis Gregorio Dias from the Condensed Matter Department. Under his supervision, I have worked on a project inspired on the idea of coupling Majorana fermions with quantum dots. My intention is to explore the manipulability of Majorana fermions in a double-dot system. The last few months have been full of excitement as the simulations started to reveal some intriguing results. In turn, embarking me on the task of creating a theoretical model to explain these phenomena. It was difficult. The model was complex and quite entangled, but after months of hard work, I finally created an algorithm by borrowing some tools from computer science. This turned out to be a clever solution to the problem that can be applied to more general systems. Moreover, the model matched very well with the simulations, hence completing my project. One of the brightest points of this Master is that it allowed me to understand what research is about. I learned that research leads to a wide variety of experiences. Sometimes the results are not the expected and the data does not make sense. Sometimes that unexpected data turns into something new and exciting. Then, the best you can do is to enjoy the process, keep a clear objective and continue working. Right now I am writing a paper presenting my results. I expect to send it for publication in the following months.

Aside from this research project, these years in Brazil have been an enriching experience. I have learned Portuguese and gotten a fantastic cultural exchange. In the academic field, I took advantage of the large condensed matter community in the country to participate in conferences, present my advances, and increase my knowledge of topological materials and solid state physics. These activities, paired with many hours of individual preparation, allowed me to improve my communication skills including my writings, computer designs, and presentations. I am using these skills right now while writing the paper, and I intend to use them at BU in my future papers, classes and conferences. Finally, this masters greatly enhanced my numerical skills as a result of my research project, and the additional training on machine learning, tensor networks, and NRG algorithms.

My years in the master's program endowed me with a particular interest for condensed matter approaches that are applicable to problems in computer science. This not only involves quantum computing but also similar ideas such as quantum annealing and more recently the quantum simulation of classical computing. The condensed matter faculty at BU has a wide diversity of faculty professors tackling these problematics. Professor Cristopher Lauman takes an approach based on Majorana architectures, similar to my research project. On the other hand, Professors Claudio Chamon and Andrei Ruckenstein developed recently a condensed matter reversible classical computation protocol that can be simulated through D-Wave's quantum annealer. These projects are very interesting for me. In addition, I am very interested in meeting Professor Gregg Jaeger from the mathematics department, who is renowned by his contributions to quantum information. The proximity to Harvard, MIT and IBM are also very exciting. All of these opportunities make BU one of the best places to do quantum research. I am confident that in this environment I will rapidly find a place where I could exploit my abilities and continue contributing to this area. I am sure that after completing my Ph.D. I will be fully prepared to research in quantum computing at any top-level institution in the academia or the industry.

I have been at Boston a couple of times while visiting my brother. I got to visit BU as well as other universities and museums. This was one of the best experiences of my life. I am now eager to come back to join the huge race to build a quantum computer.

Thank you for your consideration,

Jesús David Cifuentes Pardo