Personal, Background, and Future Goals Statement

My first physics class as a high school student came during junior year, at a stage when I was growing increasingly tired by the lackluster high-school science curriculum. Physics class finally presented a challenge compelling enough to demand my full and undivided attention, and soon renewed my earnest affection for math and science. However, I still harbored a secret suspicion that my abilities were not truly something to be proud of at all, but considerably behind those of the rest of the students. I struggled to finish tests within the allotted time, and I always seemed to be the last one still working on the labs. I heard classmates in the hallways boasting about how well they did on the physics tests, even though they had not studied, and almost felt ashamed of the hours I had spent. The crushing blow came one class when the teacher had the idea that the next lab might be more fun if the students divided into teams and made it into a competition. The details of the experiment and why it lent itself to a competitive format have long sense faded from memory; the only thing I do remember was the team draft, when the teacher announced “and every team has to have at least one girl.” The guys began to groan, and my heart sank. As the number of unselected students had dwindled, the four women in the class sat conspicuously until the end. They were chosen unceremoniously, with none of the enthusiasm with which the other students called out to their male peers. I was the last one left seated. The incident seemed to confirm everything I had been secretly dreading, that my confidence in my abilities had been entirely misplaced. Clearly, I thought, my peers had noticed what I had been too self-absorbed to realize: that no matter how much I enjoyed it, I was not cut out to be a physicist. I spent high school avoiding physics and math related extracurricular activities. I was afraid to ask questions for fear of seeming stupid or ignorant, and terrified to attempt discussing physics with my peers.

In the summer of 2016, I was lucky enough to get the chance to experience actual physics research, and this tragically distorted outlook was overhauled completely. I was accepted by a program designed to promote the involvement of underrepresented groups in STEM research at Oberlin. I was finally surrounded by fellow students, many of which had far more physics experience than I did, who were willing to speak to me as a respected peer, and explain things to me that I did not know without reverting to condescension or expressing any of the familiar signs of contempt. My advisor and fellow lab workers believed that I could make a real contribution to experimental physics, and I was inspired to live up to those expectations. My fellow students and I would explain our projects to each other, learning more about physics by encouraging rather than posturing, and I was rewarded for my trust and constant inquiry by the rapid expansion of my physics understanding.

The passion for fundamental physics research that was sparked that summer has grown as I have gained more experience. Research is a task through which the full force of my often- scattered attention is finally focused down on a single problem, and my habitual intensity is finally given direction and purpose. Solving problems in physics often comes down to building the right tool: whether that tool is new code designed to sift through collected data and identify patterns, electronics to correct or stabilize existing equipment, or an entirely new experimental setup. I have come to appreciate that every unsolved problem is a chance to bring something new into the world.

The intensity that physics research brings out in me is certainly one of the things I love about it, but devoting so much energy to a task can also make life frustrating and leave me exhausted. Through experience, I have learned that the best way of rekindling my energy and excitement is by sharing with others. Teaching physics is a major source of my inspiration, which I use to fuel my energy and keep my enthusiasm high though difficult periods of research. The resilience to adversity that this cycle promotes has allowed me to find success both academically and in independent research.

The first research experience I had during summer 2016 has been one of the defining moments of my life. I worked with Professor Jason Stalnaker on a project doing precision spectroscopy of lithium using an optical frequency comb, a mature experiment in a stage when most of the necessary work was put into reducing systematics and improving the stabilization of the probe laser. On this project, I gained many essential research skills: cleaning and aligning optics, using a Fabry-Perot cavity, dis-assembling and re-assembling an external cavity diode laser and stabilizing and scanning the wavelength using feedback controls. I was drawn to this experiment not only by the hands-on, highly controlled nature of the experimental techniques, but also the theoretical and computational work that went into modeling the signals and fitting the resulting data. In the summer of 2017, I participated in a research experience for undergraduates (REU) at BYU, working under Professor Steven Turley on developing instrumentation for fabricating and characterizing thin film aluminum mirrors for use in large bandwidth space-based telescopes. My role on the project was primarily to develop the program used to remotely control the fabrication and reflectance testing processes. My most important achievement that summer was to hone the valuable skill of quickly learning an unfamiliar programming language. I had little practical coding experience at the start, but the demands of the REU taught me to quickly adapt my thinking to a new language, and as a result, I have become both a capable and flexible programmer.

I left the spectroscopy experiment during the spring term of 2018, when Oberlin joined the Global Network of Optical Magnetometers for Exotic physics (GNOME). GNOME is international collaboration using a network of optical magnetometers to search for exotic spin coupling, a process that could eventually lead to determining new constraints on the theoretical properties of dark matter. I entered the project alongside another student with the goal of applying what we learned working together on lithium to build a Spin Exchange Relaxation Free (SERF) magnetometer. This proved to be a valuable experience, combining working aspects of tabletop experiments that had drawn me to the previous experiment with a larger motivation based on cutting down the unexplored parameter space that represents a major gap in the modern understanding of physics. That summer, I joined another lab focused on big questions of fundamental physics as part of the WAVE program at Caltech, where I spent 10 weeks doing research with in the Hutzler lab, a group searching for symmetry violation using polyatomic molecules. I arrived for the summer with the goal of designing and building a simple system to frequency stabilize a laser against slow drift at an arbitrary wavelength. Like the previous summer, I spend the beginning becoming familiar with a new set of tools: in this case 555 counters and other discrete electronics. The project ended successfully, and I gave a short presentation on the completed prototype. In the fall I once again became heavily involved with GNOME, on the data analysis rather than the experimental side, adapting a method developed by LIGO to pick out transient deviations from noise from the station magnetometers. I also inherited from graduated student collaborator the task of checking for consistency of the measured signal amplitudes with the sensitive axes of the network magnetometers. I assumed a leading role on this specific branch of the GNOME analysis and as a result, I became much more involved with the larger collaboration. Results where shared at biweekly Skype meetings, where time was limited and attention easily lost. To receive useful feedback, I practiced presenting the problem in a way that could not only quickly convey the important information, but also convey a sense of why the rest of the collaboration should care. Once the collaborators could share some of the enthusiasm I felt for my own work, they were eager to volunteer advice and willing to put time and effort into finding a solution. Successfully moving forward with the project relied critically on bringing people together in this way; when I ran into an issue that impeded progress, I learned to clearly communicating what the issue was and why it was an interesting problem, then listen to their ideas, and finally independently synthesize the external input to solve the problem. My goal in attending graduate school is to build a career where I can engage in both research and teaching. I want to bring my enthusiasm, intensity, and experience to work on carving out the blank spaces in parameter space, looking for clues that could help facilitate the next step in our understanding of physics. I also intend to do my part to help recreate an inclusive, healthy learning environment, and keep sharing my knowledge to keep my enthusiasm fresh. I hope to be able to take an active leadership role in graduate school and beyond to help spread public awareness and appreciation for physics.

Intellectual Merit

Having engaged in some form of physics research consistently throughout college, I have developed many of the important technical skills and familiarity with common instruments used in AMO physics, and learned what the low-energy experiment process is like at different stages of an experiment. Additionally, because Oberlin is an undergraduate only institution, senior undergraduates are able to take on the roles in the lab normally occupied by graduate students, and so I was able to take on a major role in directing my own research projects at Oberlin. An example illustrating the skills I have mastered over the course of my college career is the meeting during summer 2019 in Mainz, Germany. Attached to the end of the Workshop for Optically Pumped Magnetometers (WOPM), the collaboration meeting was attended by

members of the collaboration as well as several workshop attendees who had heard about the

collaboration and wanted to know more. Also in attendance was a group of theorists who wanted to learn more about GNOME and provide input about theoretically motivated models to which GNOME could be sensitive. At the conference, I represented the Oberlin and East Bay joint data analysis and gave a 30-minute talk explaining the Axion-star search that I had played a leading role in developing. I was able to present a characterized product that could locate simulated bursts in the magnetometer data, find coincidences between stations, and either produce the magnitude and direction of the event that triggered the signal based on the relative amplitudes in the different stations, or veto the triggered signal as a coincidence inconsistent with a directional model. However, the real success of the talk was in the reactions of the participants. After giving the talk, I was approached by one of the theorists, who wanted to know more about the analysis and provide suggestions for modifications that could help improve the method. I was told that a professor from the University of Michigan, who was not part of the collaboration, tried to learn more by searching for my name on the Oberlin faculty website. Finally, two GNOME members spearheading another branch of analysis met with me after the meeting requested a slide-by-slide walkthrough of the presentation, going over the details passed over by the main presentation. It was clear that I had successfully realized my intentions: the audience understood the key ideas of the talk, and was excited to learn more and volunteer their time to help.

Broader Impacts: My life would likely have taken a drastically different direction if not for my early summer experience, and I know first-hand how the learning environment can make or break a budding career. I carry with me the memories of what physics should feel like, where sharing ideas is encouraged and no one is afraid to question everything or admit when they are wrong. I am working to become the kind of leader who will foster this kind of environment and inspire other students like myself to realize their potential. I have volunteered by leading physics demos at an elementary school STEM camp, worked as a lab assistant for introductory physics lab, and have worked for two semesters as the designated tutor for two math courses taught at Oberlin: multivariable calculus and differential equations. Both courses are required for physics majors, who tend to make up the majority of the class, and multivariable calculus in particular includes many first year students who are only just encountering the notation of vectors and higher-dimensional functions. At Oberlin, the required math courses are a critical part of the physics curriculum, however many students also tend to find it highly intimidating. At a recent multivariable problem session, an anxious first year attendee asked me if they would need to understand this material in order to do physics, saying “I’m so confused, if it’s always going to be like this I don’t think I can do it.” Unfortunately, this attitude is common among the multivariable students, who are not yet familiar with the environment and are still sometimes nervous about speaking with the professors. Aware of the potential impact I have at this turning point in their careers, I have done my best to dispel the dread that hangs over the unfamiliar notation and replace it with enthusiasm, by showing the students how to break down the problem and recognize connections to the basic, fundamental problem types they have learned. I give students the problem solving strategies and mathematical tools to approach challenging problems, and watch their confidence and enthusiasm grow as they recognize familiar structure in problems that seemed impenetrable, and begin to work their way towards finding solutions on their own. When I do my job well, the students leave the session feeling empowered and excited once again, and I am ready to take my own advice and face my own tasks with renewed eagerness.