Personal Statement:

"The world needs mathematicians."

My high-school calculus teacher's words rung true. He described how integrals were utilized to obtain the probability of events following a distribution. He engagingly explained how many population phenomena are "almost" Gaussian. However, the world is often more complicated than simple functions can describe, and advanced techniques are needed to model the toughest problems, which so often have more complex properties than manageable by a bell curve.

I was immediately hooked on the mathematical underpinnings of the content and seeing the power of math in the real world. I've continued to do this throughout my academic career. In my portfolio optimization class, I learned about convex optimization through the lens of finance. A common computation in portfolio optimization is the matrix inverse. When programming the efficient frontier with real data, I became familiar with the computational inefficiencies of this task. After conversations with my professor, I learned just why this task was so slow, and he encouraged me to find techniques to make my code more efficient. This process was addictive; I was able to measure how long my scripts would run in seconds instead of minutes.

Solutions and theorems are only as useful as they are able to be wielded efficiently. Throughout my research experiences, I have worked hard to make theoretical foundations clear, and computation efficient. Through this lens, I have had the opportunity to work on problems with advanced mathematical underpinnings and real-world application.

Relevant Background & Intellectual Merit *Research:* Entering college, I knew that I wanted to be an applied mathematician, and I grew from an interest in biological applications of mathematics to computational optimization. In the summer of 2020 at the Yale School of Medicine, I assisted in computational data analysis to look for evidence of evolution in B cells after a certain vaccination has been applied under Dr. Steven Kleinstein. I focused on writing data analysis scripts for analyzing vaccine data, frequently meeting with my research mentor, a Postdoctoral fellow. It was a great opportunity to learn how research science operates. I contributed to our paper's growth from an initial rough draft, to a preprint manuscript, and finally to an accepted publication in eLife Sciences. I saw the peer review process in action and how it improved the integrity and quality of our science. From this experience, I knew that I wanted to pursue a career as a researcher, as it perfectly encapsulates my desire to learn more about the world around me and have an impact.

In the summer of 2021, I was selected to participate in a NSF REU program at the University of Wisconsin - La Crosse. I learned topological data analysis (TDA) under Professor Wako Bungula and Dr. Danelle Larson. My team applied the TDA Mapper algorithm to quantify ecological states in the Upper Mississippi River. This project involved a high degree of synchronous work. I further developed my ability to write clean code, explain content concisely and effectively, as well as efficient data management. In my team of six students all working simultaneously, it was vital to make sure that we were all communicating our choices of data analysis techniques. This allowed for easy and immediate comparison of our results. These skills allowed everyone to explore different parameters for the Mapper algorithm simultaneously. Due to the quality of this process, we were able to produce two publications from our summer REU experience. One publication in PLOS Computational Biology focused on the TDA results, while the other focused on our data cleaning process with data interpolation methods in Oceanography and Limnology: Methods. The results of our work will be utilized by the US Army Corps of Engineers when deciding on where to deploy certain restoration projects, as it gives them quantifiable metrics for evaluating the success of a particular project.

While I am grateful for these experiences in mathematical biology and ecology, I found myself more interested in learning about the methods we were currently employing throughout the projects. In particular, I found it quite interesting how many machine learning models are cast as optimization problems. That led me to the discovery of the world of mathematical optimization and I was eager to become a contributing member of this field. Optimization provides a unifying framework for an applied mathematician to contribute to multiple high impact application areas.

During my junior and senior years, I have developed a mixed integer linear fractional program to optimize the benefit to cost ratio for runaway and homeless youth shelter deployment in New York City under Professor Andrew Trapp (WPI), Professor Renata Konrad (WPI), and Professor Kayse Lee Maass (Northeastern University). My idea funded me as an NSF REU student during the summer for this work. My research allowed us to compute the optimal marginal deployment of new shelters and shelter resources in the city. We are currently in the process of preparing software that will allow decision makers in New York City to utilize our model when preparing to create new shelters.

For this project, I dove deep into the optimization literature, further validating my passion for the field. I learned the power of mixed integer programming and gained exposure to operations research. Through this interdisciplinary experience, I was able to develop an algorithmic framework for decision problems in the social sciences, combining two seemingly distant fields in a unique way. Through group meetings and presentations to a diverse audience, I further improved my skills as a communicator by presenting in group meetings to an audience of mathematicians, industrial engineers, and social scientists. I served as the lead author for our manuscript, moving the project forward through the review process. I presented this work at the 2022 INFORMS Annual Meeting, and was awarded the INFORMS Scholarship for funded travel for attendance (one of four awardees, where the other students were from The University of Southern California, Rice University, and Bucknell University).

I completed my senior thesis under Professor Stephan Sturm, studying backwards stochastic differential equations (BSDEs) and deep learning methods to numerically approximate their solutions. The application here was option pricing in mathematical finance. Since I started my senior thesis research a semester early, Professor Sturm suggested that I apply to the 2022 SIAM Gene Golub Summer School, which focused on financial analytics. While these summer schools are primarily for graduate students, I was accepted to this program, and was fully funded to travel to Italy to speak with researchers from all over the world about mathematical finance's recent developments. The sense of community was phenomenal, and it was very exciting to hear about recent work in the field. In particular, it was interesting to see that optimization was a driving force in developing algorithms to solve many financial problems. From the courses in the summer school, we created a presentation demonstrating what we had learned. Our presentation discussed how deep neural networks can effectively approximate many functions, making them effective tools for financial problems. I focused on the application portion of our presentation, and made sure that it followed from the theory that the other students discussed. In Italy, I learned that graduate school would be a great next step.

My senior thesis was a great opportunity to combine the computational power of deep learning and stochastic analysis in a real world application. I proved fundamental existence and uniqueness results for the solutions to BSDEs and reflected BSDEs (BSDEs with a boundary constraint). I implemented multiple deep learning schemes for numerically approximating solutions to compare across the methods. My report introduces BSDEs from elementary probability theory and documented the proofs and numerical results from the research. For this work, I received an honorable mention for best senior thesis in the math department that year. Additionally, along with Professor Rohini Kumar (Wayne State University) and Professor Hussein Nasralah (University of Michigan - Dearborn), we are in the process of drafting a manuscript to be submitted for publication.

Through these research experiences, I explored many areas of applied mathematics, finding my interest in mathematical optimization. I am currently conducting research in mathematical optimization at Northeastern University under Professor David Rosen.

Teaching: Since the beginning of my sophomore year, I have kept my fundamentals strong through serving as a peer learning assistant (PLA) in the Mathematical Sciences Department at WPI. This comes with the responsibility of running office hours, grading homework, running a weekly discussion section, and working at the math tutoring center. In the tutoring center, I am fielded with questions from any undergraduate math course. This taught me important time management skills, as I balanced my own classes while helping to run a large course. I also balanced this responsibility with my research obligations in the latter half of my college career. I was honored to be recognized as the 2023 WPI PLA of the year highlighting my contribution to the university's teaching mission. Navigating this life has made

me certain that being in graduate school is a perfect fit for my combined passions in teaching and research. I also had the chance to serve as a mentor for other PLAs, giving advice on how to prepare for discussion sections, office hours, and balancing grading responsibilities with other coursework. I always prioritize creating a comfortable environment for students to ask questions and further their own understanding of the material. I have been delighted and proud to see very favorable commentary in my course evaluations reflecting my success.

Outside of serving as a PLA, I also had the chance to give talks at WPI's PhD student seminar. The audience was primarily composed of upperclassmen undergraduates and graduate students to present their work to receive feedback on the presentation content and style. I had the chance to discuss optimization theory, mathematical finance, and operations research. I also learned how to best present proofs, and learn what it really means to be able to clearly and concisely present mathematics to a group of peers. Additionally, it provided me with a network of graduate students to learn about best time management practices for graduate studies and advisor communication.

Broader Impact As a college freshman, I was unsure of the new campus I joined. After my first WPI Math Club Meeting, I found a network of upperclassmen who were excited to provide me with advice on how to be a successful undergraduate math student at WPI. During my time at WPI, I became the President of the WPI Math Club I had joined in my freshman year, working hard to create an inclusive and welcoming environment where students of all backgrounds, and with different levels of mathematical expertise, can join, share their passions and learn from each other. During my tenure, I was able to make the club more diverse and worked hard to create a welcoming environment for everyone. Through our events with the department, I helped to provide a link between the department faculty and undergraduate body. Members of the club were able to provide input on special topics courses and attend colloquia to learn about many fields of math typically not visible to undergraduates.

Recently, the WPI Math Department piloted a mentoring network, where junior math majors are paired with freshmen to help them navigate life as a WPI math major. Knowing how useful having upperclassmen friends is from my own past, I immediately joined the program to share the advice I had gotten years ago as well as my own experiences with students. This experience has also allowed me to invite many new people to participate in the Math Club, ensuring its continued growth. This mentoring network has now continued beyond its pilot, providing underclassmen with a more immediate and accessible resource as they chart their studies at WPI.

At Northeastern, I hope to become a contributing member to both the mathematics community, as well as the university as a whole. I am participating as a mentor in the directed reading program for undergraduates. This will involve helping students read more advanced textbooks and research papers, serving as a reference for ideas and assistance with writing and presenting a report.

Future Goals A PhD will give me a stronger theoretical foundation to conduct more advanced work in computational optimization. I hope to develop mathematical theory that is practically useful in implementation. Without computationally tractable algorithms to achieve optimal solutions, the existence of an optimal solution is useless to decision makers. Optimization has the power to improve systems in many fields such as machine learning, robotics, finance, and mathematics. As a field with many applications, I aim to become an interdisciplinary researcher and have collaborations across many fields, combining my expertise in optimization with their domain knowledge to converge on new techniques that can benefit their fields.

I aim to be in the position of many of my professors I've worked with: simultaneously inspiring the next generation of students to apply complex mathematics to real problems with impact, while continuing to do the same myself. Through collaborations with others, I hope that my work is used to help people and organizations to solve problems that they face in their lives in a meaningful and impactful way.