

Tricks! “Tricks” have always inspired my passion and relentless drive for solutions and mastery. Before college, I devoted my free time to conquering the physical skills and knowledge required for high-level skateboard tricks. Silly? Not if you consider that I was unwittingly training myself in keen observation, physical dynamics, intense mental focus, hard work on fundamentals, imaginative application of available tools, teamwork, and personal initiative. Toward the end of high school and at NYU, my interests in seemingly mysterious physical phenomena evolved into an immersion in mathematics.

My passion for mathematics deepened during my research at Yale University where we searched for a hypothetical sterile neutrino. There I optimized our data collection pipeline using pulse shape discrimination and built a simulation of the detector that incorporated realistic photomultiplier tubes and quantum efficiency curves. Using my simulation we were able to design a light-guide that collected 30% more photons and increased detector uniformity. In between writing code and taking samples in the lab, I began exploring the mathematics behind neutrino oscillation which led me to the world of linear algebra. I learned about mixing matrices and angles, but also more foundational material about unitary transformations and operator spectra. As I wrapped up my time at Yale, I presented a poster at a large conference and published two papers with the collaboration.

In my third year, I took a reading course on differential geometry which was solely discussion based. Embracing this format, I was stunned how easily direct, imaginative, and new discovery became. I learned about classical differential geometry, and even built a cardboard and string model of a hyperboloid to demonstrate how it was doubly-ruled. We also dove into topics like manifolds, the Gauss-Bonnet theorem, differential topology and surgery theory. Bettering my presentation skills through weekly reports to my peers plays into my ultimate goal of collaborating on research teams and teaching at the university level.

The following semester was difficult for me: a more painful learning experience. After slipping behind academically, and losing my grandfather, I ended this semester with my lowest course grade ever. The semester was not a total disaster though, because the difficult courses forced me out of my comfort zone. *Thermodynamics and Statistical Physics* showed me I wasn’t used to thinking in combinatorial terms, and *Topology* pushed me to understand deeper facts about local and global properties such as connectedness. I live, and believe in, the principle that failure often presents an entry point to a better path toward solution and success.

Working with Prof. Luciano Medina on *optical vortex solitons*, our mission was to prove the existence of solutions for a class of nonlinear Schrödinger equations. Using a variational method, we reframed the problem in the language of functional analysis and operator algebras. Doing this allowed us to use powerful tools from analysis and apply them to a functional which we were trying to minimize. We were thus able to give necessary conditions for nontrivial solutions and prove the existence of solutions via constrained minimization. To further understand the problem, I computed solutions using python and verified the numerics from previous papers. While the work was highly specialized, it bolstered my fundamentals in functional analysis with topics like

Sobolev spaces, Trace operators, measure theory and lots of numerical computing as well. This work led to a poster presentation for NYU faculty, and talk at Rice University.

Although my program did not require a thesis, I chose to write one on Q-Balls (a non-topological soliton) knowing it would help prepare me for future research. Studying the foundational classical and quantum field theories which underlie much of our work allowed me to give physical explanations as well as mathematical ones for our results. Through proving integral inequalities and functionals to be lower semi-continuous and coercive, we showed spherically symmetric Q-Ball solutions existed. This experience taught me lots of technical material about functional analysis, but my real takeaway was the knowledge that I enjoy research that touches both pure and applied mathematics.

This has largely drawn me to fields that are both computational, and mathematical in nature. I've been particularly fascinated with formal verification, and automated theorem proving as both are deeply intertwined with mathematical foundations, but require a thorough understanding of software and its development as well. Given Carnegie Mellon's role in developing the LEAN theorem prover, I believe CMU to be an ideal fit for pushing forward the forefront of automated theorem proving and the computer-mathematics interaction.

After graduating from NYU I opted to take a job as a software developer/data scientist at the academic writing enterprise; Overleaf. Having no professional software experience, I was nervous that I was in over my head. However, I quickly demonstrated that I could pick up necessary skills on the job. My time is split between working on our web application, and handling requests for data from our marketing team, but even do \LaTeX support. Most importantly though, this job has taught me organizational skills that will benefit me as a graduate student.

Overleaf has also sent me to a multitude of mathematics conferences to represent our company. While I am at conferences to interact with users, I have the freedom to attend talks and lectures as I wish. This has allowed me to further explore areas I'm interested in and have attended talks ranging from modelling pedestrian dynamics, to applied category theory. All in all becoming a more proficient programmer has only strengthened my mathematical ability. Running simulations of shuffling cards, building computational models of dual numbers, and learning about interactive theorem provers such as LEAN and Coq are just a few examples of how programming has helped deepen my mathematical knowledge. Maintaining this connection has allowed me to grow my enthusiasm for the mathematics, and develop a more specialized interest in automated theorem proving, formal verification and homotopy type theory.

My treasured moments (in skateboarding and research) have resulted from discipline, struggle, and trust. Through research, experimentation, and eventual teaching, I believe I will pursue significant questions successfully. Determined to pursue research that is deeply mathematical, computational, and philosophical, CMU's joint Pure and Applied Logic program will be excellently suited for the interdisciplinary research I hope to engage in. Given the similarities between my academic interests, Carnegie Mellon's research faculty and environment, I trust this program will help me succeed in my mathematical pursuit. And I may skateboard around Pittsburgh as well.