During my senior year at Carnegie Mellon University, I joined Professor C. Fred Higgs III's Particle Flow and Tribology Lab, where I carried out research on "Numerical Modeling of the Soft Elastohydrodynamic Tribosystems." The lab has a working nanoscale simulation code, custom-made by the lab using Mathematica. It simulates systems involving two rough, deformable surfaces, rubbing against each other in the presence of an interfacial fluid filled with nanosized particles. Some of the broader impacts of this work include modeling of hip and knee replacements and other medical ball-and-socket devices, as well as predicting how they will wear over time and consequently how to make them last longer. It also has applications to modeling hard disk drives, next generation bearings, and a key process (chemical mechanical polishing) in microchip manufacturing, which is critical to improving integrated circuit complexity.

Such a system incorporates a variety of different physical regimes and, quite impressively, the lab's code is a purely first-principles simulation that does not use empirically fitted variables (no "fudge factors," just physics). Of the different kinds of physics included in the model, contact mechanics is used to calculate how the pliable surfaces behave. The lab had been using an old contact mechanics model, which was 1-D, analytical, and generally poorly suited to a numerical finite-differencing approach. I examined a more advanced 3-D discrete contact mechanics model [1]. I researched the model and taught myself the required programming background to understand the lab's existing code. With assistance from a graduate student in the lab (approximately one meeting every 2 weeks), I successfully integrated the new model, replacing the code's old contact mechanics physics. With this upgrade, the code can now calculate the net strain at each point as a superposition of strains from the stress at every other point, instead of using approximate macroscopic averages as it used to. The lab is now working on finalizing and submitting the journal paper that will contain my work.

This experience affirmed both my love of research and my ability to independently teach myself necessary background to get up to speed on a new topic. It also showed me how rewarding research and improving a technology to serve society can be.

Between the academic years, I spent two of my summers interning at Apple Inc. During my first summer, I helped design the click dynamics of the Magic Trackpad, a stand-alone wireless trackpad. I independently created my own 3-axis accelerometer testing setup to measure the response of the trackpad's click when varying its mass and chassis geometry. I then compared the signals to control samples from other devices, using MATLAB to analyze the results and identify the governing physical parameters and how they controlled the product's response. From this, I was able to advise the project lead on design specifications, leading to successful prototypes. The final product was released shortly after my internship, incorporating design changes resulting from my work. I also presented my work to the Vice President, and was selected as one of a few out of roughly 30 interns in my department to go on to present my work to the Senior Vice President of Hardware. Working on this project gave me valuable training and experience, and again provided a sense of fulfillment for working on a technology with broader impacts. The Magic Trackpad gives desktop computers trackpad capabilities, which are required for the multi-gesture foreign language character input on Mac computers, which allow the computer to be more accessible to people of varied cultural backgrounds. The Magic Trackpad also enables desktop computers to run a multitude of gesture-input enriched educational programs, which can then be used directly in middle schools and high schools.

During my second summer at Apple Inc., I worked primarily on the Smart Cover, which is the cover for the iPad 2, released in early 2011. Its key features are to magnetically attach to the side of the iPad 2 (and self-align), wake/sleep the iPad 2 when it is opened/closed, and fold into a triangular form that can brace the iPad 2 in either a shallow "typing" angle, or a steeper "movie viewing" angle. It accomplishes this by means of 4 panels connected by flexible fabric hinges, which can collectively roll up into the triangular base.

When I joined the iPad accessories team back in 2010, the idea of the smart cover was still far from maturity, with only a handful of engineers working on its mechanical design. We brainstormed several design ideas including tabs, Velcro, bistable hinges, snaps, and multiple panels. I then, of my own initiative, used MATLAB to create a geometric model of the four-panel design and numerically optimize the panel widths for their intended functions. Through this, I was able to demonstrate that this design worked, and that there was exactly one ideal configuration for the different panel widths, which I was also able to calculate. This saved the team what would otherwise have been a lot of invested time and money in different prototypes that would have been doomed to fail or be sub-optimal. Today I can proudly say that any time you see a Smart Cover on an iPad 2, the panel dimensions are what they are because of my calculations and design work.

Concurrently with my work on the cover geometry, and using electromagnetic field simulation software that I acquired for the company, I modeled the magnetic field that dictates the very delicate and precise location of the gaussmeter embedded in the iPad 2, calculating its optimal position. The gaussmeter is the magnetic field sensor responsible for the wake/sleep function of opening/closing the cover. I was also able to use this software to analyze the configuration of the magnet array employed in the main hinge of the cover that is responsible for the cover's self-aligning nature when magnetically attaching to the iPad 2, and ensure that it satisfied industrial standards for field leakage limits for credit card safety. As a result of all my work, I was named inventor on eight patents filed by Apple Inc. (still in filing). Months later, the program director mentioned how he still uses my MATLAB program as an example to others of excellent up-front analysis.

While in a different field from my research proposal, these internships gave me tremendous experience working efficiently on teams, presenting and sharing my work, and making decisions independently.

Currently, I am working during my first semester in graduate school on building an electrothermal testing setup to measure the in-plane thermal conductivity of cobalt and nickel nanowire cloth. This will be a quick starter project specifically to train and prepare me for my primary research proposal. I am working with one other lab member, a visiting professor from Japan, who is mentoring me on how to use all of the equipment, as well as how to design and build circuitry, lab software, samples, sample holders, and project boxes. This project is progressing quickly and should be completed within a few months, at which point I will have learned most of the equipment and protocols necessary for my proposed research project. I will also participate in the high school outreach program set up by my research advisor, and, once I am more settled, recruit an undergraduate to mentor and to assist me in my research.

[1] M. A. West, R. S. Sayles., Interface Dynamics: Tribology Series, 12, 195-200 (1987)