Jay Mudholkar

Personal Section:

Ever since I was young, STEM (particularly physics and engineering) topics and applications fascinated me. Beyond enjoying learning the material, the fascination also derived from how STEM was a way for me to help the world—I have always been problem-solver. My beginnings trace back to elementary school, whether it was helping my friends make-up or figuring out the most robust pokemon armada.

As a high school sophomore five years later, I had a discussion with my music school's president Ken Kuo about researching the design and production of carbon fiber musical instrument cases. The project would allow me, again, to connect my multifaceted life. It would allow me to connect piccolo/flute and STEM.

This research became my most beloved year-round extracurricular activity, especially because of its bifurcation even within the realm of mechanical engineering. Technologically, I use AutoDesk Inventor CAD (Computer Aided Design) software and CNC (Computer Numerical Control) milling, which allow me to design and create physical models of each product. Theoretically, I create uniquely dimensioned instrument cases through mathematical analysis of the contoured geometry using, in large part, multivariable calculus. The multi-level linking is kind of mind-boggling--on the micro level, I’ve connected practice with theory (within mechanical engineering); and on the macro level, I’ve connected mechanical engineering and flute/piccolo!

My success exploring the carbon fiber research project had a strong impact on me. I wanted to explore something theoretical the summer going into my senior year to diversify my research background. At the end of my junior year, I was accepted into the Clark Scholars summer program at Texas Tech University, and reached out to Prof. Sukalyan Bhattacharya to be my research mentor through the program, which involved seven weeks of intense research. The research idea originated from a meeting between myself and Dr. Bhattacharya, where we discussed exploring the effect a viscous liquid would have on a bubble-laden liquid droplet, and we agreed it would be an excellent option to explore through the Clark program.In June, we did indeed choose to research the viscous-fluid system, and there began my pursuit to learn the art of theoretical research. At Clark, I was working full-time on this project during this time, and also lived on campus. Several late nights and weekends were spent as the project progressed, since new findings usually resulted in additional work that validated and further supported the project. At the conclusion of the Clark Scholars program, the project was formally presented to the Program Board, which included my mentor as well as the Dean of Texas Tech Honors College, who chaired the Clark Scholars program. I have continued to keep in touch with my mentor and in the summer going into my freshman year of college, I am returning to Texas Tech to conduct follow-up research with him.

In conducting the research, I had to learn a lot of new mathematics. I had exposure to Calculus and Differential Equations from math classes at my high school, but understanding the vector and tensor algebra and physics behind fluid dynamics was a whole different story. However, my mentor was so helpful and encouraging for me to learn and grow: it was absolutely amazing to learn from him and be able to create such wonderful work.

My research experience(s) has/have inspired me to further pursue high-caliber STEM research in a multitude of ways; but most importantly, it gave me the identity of an engineering researcher—both practical and theoretical. I want to use my identity to change the way we as a society perceive research. I am so glad to have taken the work and effort to pursue STEM research in high school--it has given me a drive to pursue something very meaningful to me for the future.

My advice to high school students looking to work on a research project that combines science and mathematics is to be invested in learning a lot of new things and keep an open mind—as high schoolers, there's a lot of mathematics we are unfamiliar with, and sometimes it's easy to get overwhelmed. However, I would say that the beauty of combined science and math research is that you learn so much about mathematical theory that can be applied to the science—a double-pronged approach, if you will! It's a fantastic opportunity, and with an open mind and willingness to learn it becomes that much better and more rewarding.

Research section:

As aforementioned, I was accepted into the Clark Scholars summer program at Texas Tech University, and reached out to Prof. Sukalyan Bhattacharya to be my research mentor through the program, which involved seven weeks of intense research. The research idea originated from a meeting between myself and Dr. Bhattacharya, where we discussed exploring the effect a viscous liquid would have on a bubble-laden liquid droplet, and we agreed it would be an excellent option to explore through the Clark program. In June, we did indeed choose to research the viscous-fluid system, and there began my pursuit to learn the art of theoretical research. Following up on my main idea of exploring the effect a viscous liquid would have on a bubble-laden liquid droplet system, The research began by designing the course of analysis (which involved building 2x2 and 4x4 matrix solutions) with Prof. Bhattacharya.

The governing equation to start the research was based on the Navier-Stokes equation. This equation, along with relevant boundary conditions, would be necessary in order to evaluate the assumed physical geometry. With these formulations, we constructed matrices which represented the rotational and deformational blocks of the surface waves. The mathematical theory, as well as subsequent data analysis, would use vector-tensor algebra, partial differential equations and programming to construct numerically significant and telling results.

This research describes how a concentrically embedded bubble alters the surface wave of a suspended viscous drop. The analysis considers small amplitudes of the interfacial pulsation so that the nonlinear convective terms can be neglected in the flow equation. The consequent linearized system is represented by a matrix formulation which predicts the natural frequencies and decay constants for different modes of oscillation. The involved matrices have a block diagonal structure separating the deformational and rotational groups. The presented work includes the mathematical derivations for both groups proving that the former manifests both oscillating and decaying features while the latter only exhibits monotonic decrease. The results reveal the variation in decay constants with bubble-drop size-ratio for different rotational modes. Once the matrices were constructed, we agreed that Mathematica seemed the most appropriate tool for the application.

The analysis involved setting the determinant of the matrices to zero, which would generate eigen parameters. Using Mathematica, the matrices were programmed in and plots of the eigen parameters were graphed. After obtaining numerical solutions to the 2x2 matrix, we obtained results for the decay of the oscillating surface waves. The mathematical values we got from this matrix can be used to help us better understand the way surface oscillations decay. Subsequent analyses can be done to understand the mathematical behavior of different physical geometries, such as a situation where the embedded particle is not a hollow bubble, but instead a solid particle. These investigations would utilize similar techniques in a similar system to what we did.