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Seeing is Believing: Teaching Physics with Animations

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Project Narrative

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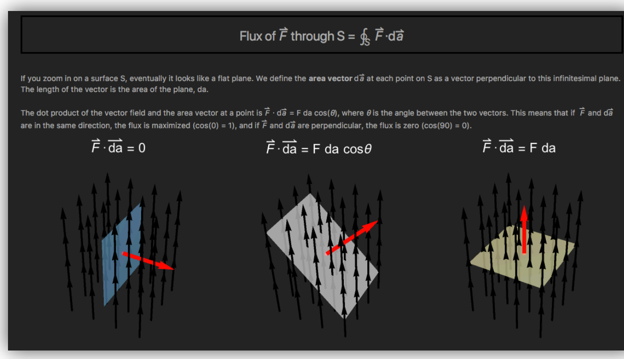
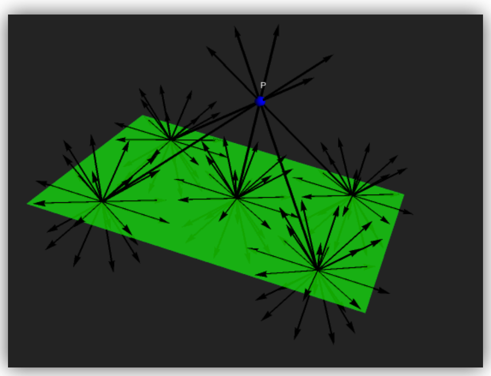
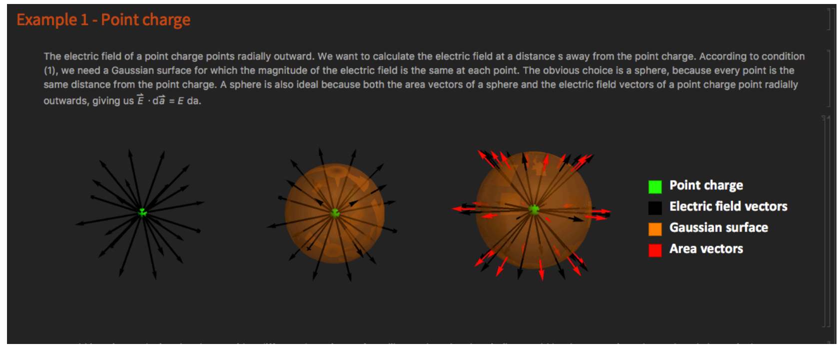
There's a reason engineering students are required to take physics courses, even though they will not likely use physics at an abstract level when they join the workforce. Besides giving students the proper theoretical background for their future work, physics increases their capacity for problem-solving and reasoning. As an undergraduate TA for a calculus-based introductory physics course on electricity and magnetism, I witnessed firsthand students struggling through problems and slowly building their problem-solving skills. However, as I taught some concepts I became acutely aware of the limitations in representing 3D objects on a 2D whiteboard. One concept in particular, called Gauss's Law, was troublesome because it relied on an understanding of spatial symmetry in three dimensions. The professor teaching the course, Dr. Allison Jaynes, asked the TAs for suggestions of how to teach this law more clearly. This is where I stepped in. Since I knew how to use a software called Mathematica, I decided to demonstrate Gauss's Law using figures that students could actually rotate, allowing them to observe the spatial symmetry for themselves rather than relying on their imagination.

I initially planned to embed my Mathematica code in a website, enabling the user to simply manipulate the figures online. However, the plugin for this technology was not updated and there was a high chance the tool would not work in the future. Plan B was to create a video of the rotating figures with a voiceover explanation. However, this removed the most important aspect of my project: the interactivity. I was in the middle of creating the video when I spoke to a student who took a class in which she could rotate 3D figures inside documents. She directed me to the instructor of her class, Dr. Keith Stroyan, who told me that he frequently created files called "cdfs," which were like pdfs for Mathematica which the user could interact with. Dr. Stroyan mentioned that he used cdfs both in his classes and his research. Though I had heard of cdfs before, I was reluctant to use them because I was worried that the requirement of downloading a cdf viewer would be a barrier to learning. However, after talking to Dr. Stroyan I decided that it was worthwhile to make a cdf even if it reduced my audience slightly because those who decided to download the cdf viewer greatly benefitted from the interactivity element.





My project culminated in a presentation to Dr. Jaynes's introductory physics class as they were reviewing for their final exam. I explained Gauss's Law while displaying my animations to a lecture hall of about 100 students. The final project, the cdf I created, is accessible to anyone with the free cdf viewer (available at https://www.wolfram.com/cdf-player/). Hopefully it will be used by Dr. Jaynes and other professors teaching introductory physics in the future to help students learn Gauss's Law in a more visual manner than it is usually taught. The explanation could be improved by adding more examples that demonstrate different types of spatial symmetry (for instance I showed rectangular and spherical symmetry, but not cylindrical symmetry). This might be a project for future physics students proficient in Mathematica.



Before I created this project, I had the idea to create an optics game to encourage people at all skill levels to be interested in physics, but my goals shifted as I learned more about the actual needs of the physics education community, and how I could use my skills as a physicist and mathematician to help meet those needs. While it would have been nice to learn how to code an entire game, what I managed to accomplish with the Gauss's Law explanation is both more useful to the physics education community and more fitting given my skill level and the amount of time I had to complete the project. In the process of creating the project, I was surprised at the wide range of classes whose concepts went into my final product. I ended up incorporating topics from electricity and magnetism, computational physics, and differential geometry. I found this encouraging because it was as if I was the person who had taken the perfect combination of classes to create this educational tool. I hope the professors with whom I shared the project continue to distribute it to their students, helping those who are struggling with understanding a 3D concept confined to a 2D medium.