Why I "love math"

David Kristofferson from The Highlands · 2 Feb 2016

[Note - Due to the chronological ordering of posts on NextDoor, please read my post entitled “The Education Series: "Nothing Great Was Ever Achieved Without Enthusiasm” before reading this one. Thanks again for reading!]

Tina commented the other day that she had two math-haters in her household, but knew that I “loved math.” Please let me explain why; this is critical to defining the proper goals in education.

If you never had a great physics teacher in school who revealed the secrets of the universe to you, then, I am sad to say, you missed one of life’s great experiences. If this makes me sound like a total nerd, the sad truth is that this makes an unfortunate statement about your educational loss, not about me. This educational failing is not rare, but is almost everyone’s shared loss. My high school physics teacher was god-awful, to be honest, and, if it was not for a few friends in college, I would have missed this wonderful experience too. Allow me to explain…

The other night I was tutoring a student in AP physics, and we were studying the Doppler Effect. The Doppler Effect, besides being a costume that Sheldon Cooper wore to a Halloween party in a Big Bang Theory episode, is the change in sound pitch that we hear when a race car passes by us while standing by the side of a race track - the “eeeee-oowww” drop in pitch/frequency. My student and I went over the algebra in the derivation of the frequency shift formula (there are four formulas to learn depending upon the motion scenario), and then we applied it in several homework problems.

This was mildly interesting, but then I turned to her and said, “Did you ever see the picture of Albert Einstein riding a bicycle?” She had; it looks like he is tilting over to the left and about to fall!

“That picture was taken at Cal Tech,” I said. Einstein went there in the 1920’s and met Edwin Hubble, an astronomer who was working at the Mt. Wilson observatory.

Earlier, in late 1915, just over 100 years ago, Einstein announced his general theory of relativity which used “the geometry of space-time” to explain gravity. While exploring its consequences, Einstein realized that his mathematical equations implied that the universe should not just be “sitting still” but had “expand.” How could the universe expand?? He couldn’t believe this result, and therefore “corrected” his equations by adding a constant to make the universe stable!

Meanwhile Edwin Hubble was using the large Mt. Wilson telescope to look at distant galaxies. He collected their light through the telescope and then used something like a prism to break the light up into its spectrum. Instead of a rainbow, he saw a series of bright lines at specific locations.

I flipped through the physics book to find a picture of the spectrum of hydrogen gas.

Other physicists had found that by running an electric current through gases enclosed in a glass tube, they could make them glow, just like a neon light. They had measured the spectra of light coming from these glowing gases, including hydrogen, and found that the spectra looked like a series of bright lines at certain frequencies instead of a continuous smear of changing color like one sees in a rainbow. (This work was fundamental in the understanding of atomic structure, a field called "quantum mechanics.")

Because stars are mainly composed of hydrogen, not surprisingly Hubble found that the spacing of the bright lines in the spectral measurements he was making looked like the hydrogen spectrum seen in the glowing gas experiments in the lab. But there was one CRITICAL difference - the frequency of the lines of light in the hydrogen spectrum were all shifted to LOWER values compared to the frequencies that had been measured from glowing hydrogen gas in the lab, but the pattern was similar.

Let's return to the "eeee-ooowww" of the Doppler Effect. The "ooowww" sound, the lower pitch/frequency sound, is how the race car sounds after it has gone past and is moving away from you. The car produces a whining noise at a certain pitch, but that whining noise sounds lower when the car moves away from you, i.e., its frequency shifts lower. The pitch sounds higher when it moves towards you.

The same Doppler effect that happens to sound waves also affects light waves. As Hubble looked at more galaxies, he found that the hydrogen spectral lines of most galaxies were shifted to lower frequencies. This meant that the galaxies were moving away from us!

*** I looked at my student and was gratified to see the "Aha!" look of excitement and understanding as the logic of this story was understood for the first time. ***

Did this mean that we were at the center of the universe? Not necessarily. Take a black marking pen and make dots on a balloon. Blow the balloon up. What happens to the dots? They all move farther apart.

The universe was expanding and Hubble had seen evidence of it hidden in the spectra of galaxies! Einstein was astounded when he learned this! Pure mathematics had told him this should be true, but he hadn't believed it!

This isn't the only time an event like this has occurred in physics. James Clerk Maxwell, a Scottish physicist, spent years studying electricity and magnetism. He summed up his theory in four equations - Maxwell's equations. He found mathematically that his equations predicted that self-propagating electromagnetic waves should exist that could travel through a vacuum. Most waves have to travel through something like water or air. The story goes that, the night after he made this discovery as a young man, he went on a date. As he and his girlfriend were looking at the stars, he said something like, "I am the only person in the world tonight who knows why we can see the stars!" True, a bit nerdy, but imagine how excited he must have felt! Einstein had heart palpitations when his theory predicted precisely why the orbit of Mercury precessed around the sun, something that Newton could not explain!

The Conclusion

A significant amount of advanced mathematics was developed to solve physics problems. Unfortunately most students never learn this, sometimes even when they are taking advanced mathematics, because of the focus on passing tests. Galileo supposedly said “Mathematics is the language of nature.” Without mathematics we have no hope of truly understanding the world, but too often math education crushes our kids. They learn to hate math before they ever get a chance to learn the secrets of our world and consequent excitement that math can unlock.

Newton developed calculus to solve problems involving the motions of the moon and planets in response to prior work done over decades by Kepler who thought he had uncovered the mind of God when he found three mysterious mathematical patterns in the movements of lights in the night sky!

On page 880 of the Calculus BC textbook used at Aragon it says, ‘We now describe one of the great accomplishments of calculus by showing how the material of this chapter can be used to prove Kepler’s laws of planetary motion.” Earlier in the book on page 320, it says “The Fundamental Theorem of Calculus is unquestionably the most important theorem in calculus and, indeed, it ranks as one of the great accomplishments of the human mind.”

I’ve found that unfortunately most students aren’t aware of these passages, or even study the Kepler’s law section, and are so harried with learning how to avoid all the traps in questions on the upcoming AP exams that they don’t want to spend the time to do so because it is “not on the test.” I also know from my teaching experience and from stories from others that the pressure is such that it leads to a lot of cheating to cope with the workload. When I worked in San Francisco, teachers told me that the problem was particularly bad at Lowell HS which is the top school in the city and requires an entrance exam for admission!!

This AP rat race is killing the love of learning in my opinion, although I am sure that there are great teachers in some schools who still manage to teach AP and keep kids excited.

Remember, “Nothing great is ever accomplished without enthusiasm.” If our kids are exhausted and learn to hate math and science, who will make the discoveries of the future that will keep our country and economy going strong???

I’ve tried to lay out the background of the dilemma as I see it. Next, I’ll address the practical problems….