Physics Integration Lesson 15 – Interpolation and Extrapolation

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Richard Feynman, Nobel Prize winning physicist, often compared the study of physics to learning the rules of chess by watching the game played.[1] Basic motion of the pieces and capture rules are apparent at the beginning. However, others rules are used less often and may not be observed after multiple games, such as castling and pawn promotion. In like fashion, some of the rules of physics (gravity, force and motion) are apparent to even novice observers. By making systematic measurements and controlling variables, these observations are translated into general principles and their associated formulas.

Given this analogy it is clear that the process of doing physics is human centered and, therefore, affected by human limitations. Measurements are made at a specific location and time. When Galileo tested the idea that all objects fall at the same rate (conditioned on gravity being the only force acting on the objects), it was limited to Pisa, Italy 1586. The reason we can generalize this principle of physics is that nearly 500 years later all over the globe this principle can be tested and found to be true. Some might argue that “the principle has not been tested experimentally on top of Mount Everest, so it might not be true there!” We tend not to take this argument seriously because the abundance of data collected at different locations in the Himalayans and at different altitudes doesn’t show any exceptions. Extending results to locations and times between measured points is called ‘interpolation’ and we have good confidence that the principle will hold.

However, what if we were to extend this principle to the interior of the sun? Would we find it to be true there too? Applying principles to locations that are distant in time and space and/or under extreme conditions is called ‘extrapolation.’ With extrapolation we do not have neighboring data points available for comparison. As a result, we must make assumptions about the nature of the universe and how those assumptions might affect the application of our physical principle.

In lab this week we explored the relationship between voltage and current in a lightbulb. Since the digital sensors can only sample at the millisecond rate, we are missing vast amounts of potential data that falls between those samples. If we are really concerned about this lost data, we could increase the sample rate and run the experiment again. I would not expect different results because interpolation between data points tends not to reveal an undiscovered physical principle. (This is not always true. If we interpolate between points small enough to reveal atoms, electrons, protons and quarks, we will find it surprisingly to be in error.) However, if your experiment only sampled data between 0 and 1 volt, you would conclude that the lightbulb is electrically no different than a resistor. Extrapolating data to 4 and 5 volts would be in error because the nature of the lightbulb changes significantly. The only way to understand the difference is to run the experiment at the larger values and develop an enhanced theory that captures reproducible behavior of the lightbulb.

1. Although it is an extrapolation, do you feel that Galileo’s observation that all objects fall at the same rate (given gravity is the only force acting on the objects) also applies to the interior of the sun? Why or why not?

[1] See YouTube video at https://www.youtube.com/watch?v=o1dgrvlWML4.

2. Extrapolating physical laws measured on earth to the whole universe is why any explanatory models in astronomy and astrophysics can be made. Do you think astrophysical models have the same level of certainty as models generated to explain phenomena on earth? Explain.