Statement of Teaching Philosophy

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Newton's laws of mechanics for a particle in an inertial reference frame can be expressed in a few lines.

- In the absence of a net force, a particle travels in a straight line with a constant speed, or remains still.
- The rate of change of a particle's momentum $\overline{p} = m\overline{v}$ is equal to the sum of the forces $\overline{F}_i$ on the particle: $\frac{d\overline{p}}{dt} = \sum_i \overline{F}_i$.
- Forces come in pairs: every action corresponds to an equal and opposite reaction.

A talented engineer, starting from these principles, can design a huge range of mechanical devices, from microelectromechanical systems to spacecraft. Electromagnetic and nonrelativistic quantum mechanical phenomenons are described in compact form by the four Maxwell equations and the Schrödinger equation, respectively.

When such a massive amount of applications lie under the aegis of such (perhaps deceptively) simple laws, why does it take four years of education for most students to begin to master the physical sciences and engineering? Partly, the difficulty arises from the advanced mathematics used in the equations. Another reason is the challenge in learning how to recognize that a certain physical principle is applicable to a given situation, and then to apply it correctly. It is possible, for instance, to treat some extended bodies as point particles for a particular problem, but a student must know when this approximation is appropriate. Still another reason is that even though the basic laws of physics are simple for single particles, physical systems on larger scales require new formulations of the laws, due to broken symmetries on the larger scales [1]. It is not a trivial matter to derive the equations of motion for a rigid body from Newton's laws for a particle. Finally, quotidian human experience may seem to contradict some of the physical laws. That objects that experience no net force shall continue to move at a constant speed contradicts our everyday experience that objects tend to slow down and stop — until we learn to properly account for friction.

How can the aforementioned difficulties inform my teaching so that I may help students surmount them and attain greater facility with the material?

A physical science or engineering class, in general, covers the motivation for studying the phenomenons associated with a set of physical laws, explaining the evidence for the laws (and perhaps a bit of historical development), and on the application of the laws. The underlying physical laws may need relatively little exposition in class in comparison to practice in applying the laws, and developing critical thinking and creativity in general. I focus on helping students recognize when specific laws are applicable and any assumptions that underly them. I work example problems of increasing difficulty in class to introduce students to varied problem solving methods and challenge them to think about the material and ask questions. Sometimes I give students problems to work themselves in class while I circumnavigate the room and help them. This practice allows the students to teach each other and so further increase their understanding.

Most engineering courses, especially introductory ones, focus on analysis. The teacher presents the concepts to the students, and they apply them to various situations in the form of problem sets. The problems are usually circumscribed in that only one correct solution is possible. This approach is excellent for teaching fundamental principles when the lectures are clear and the problems are well designed. However, it covers only half the discipline of engineering. Students must also learn to create new designs or improve upon existing ones. They must learn how to fuse the intuition they obtain by tinkering with real objects to their understanding of abstract principles. Creativity in engineering comes from a synthesis of intuition, mathematics, and physical concepts. To teach the synthesis of engineering concepts in an introductory dynamics class, I created a design project for students in which they had to analyze the performance of a device (e.g., a catapult), suggest changes based on their understanding of mechanics, and then predict the resulting improvements in performance. Students then had the option to construct models of their device and test their predictions.

Teaching, for me, is a research activity too. As I gain more teaching experiences, I will continue to observe the results of my methods, make improvements, and test them. In this way, the classroom is like an engineering design to be improved, and perhaps over time, optimized.

References

[1] P. W. Anderson. More is different. *Science*, 177:393–396, 1972.