Engineering Design

Electric Vehicle Design Challenge

Professional Development

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What is Engineering Design?

Science is the study of the natural world. This study often identifies patterns. The study and use of patterns is basically the definition of "mathematics." What is discovered can be applied "to solve problems and extend human capabilities". That is the definition of "technology." The process of developing technology is called "engineering."

Engineering Design is the process of applying knowledge of the natural world and its patterns to solve a problem. It is not discipline specific or limited to a particular age group or gender. It is, can, and should be conducted by all students regardless of academic ability or career aspirations. Engineering Design can be as simple as the informal development of a schedule to complete all of the tasks required for getting ready for school in the morning and arriving on time. It can be as complex as operating a rover on Mars.

For the past several decades, the general understanding is that an increased interest in and understanding of mathematics and science will improve our ability to solve problems leading to new inventions and innovations. The intended outcome is a stronger economy, increased national security, and an elevated standard of living. This foundation is the current interest in STEM (science, technology, engineering, mathematics) educational programs.

Why is Engineering Design Important?

The *Common Core State Standards for Mathematics* call for "an understanding of mathematics." One way this is achieved is through the full integration of Mathematics Practices throughout the curriculum. These practices consist of:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

The *Next Generation Science Standards* (NGSS) include Science and Engineering Practices as an integral part of a comprehensive science educational program. These practices include:

1. Asking questions and defining problems
2. Planning and carrying out investigations
3. Analyzing and interpreting data
4. Constructing explanations and designing solutions
5. Obtaining, evaluating, and communicating information
6. Developing and using models
7. Engaging in argument from evidence
8. Using mathematical and computational thinking

Educational standards for Technology and Engineering disciplines are not so clearly defined or as widely adopted as those for mathematics and science. The *Standards for Technological Literacy* include engineering design and the application of the design process. They also call for an understanding of "the relationships and connections between technology (engineering) and other fields of study."

It is clear that a well-designed and well executed activity in engineering design can address important concepts in all STEM disciplines. It is also possible to utilize the design activity to address content in other disciplines, particularly art and social studies. English and Language Arts concepts and skills can also be addressed.

The ratio of the car forces to the wall forces is the drag coefficient of the model. For example, if the drag force on the flat vertical wall measures 100 newtons and the drag force on the streamlined car measures 50 newtons, the drag coefficient is 0.5.

Reflection

There is some confusion concerning the use of mathematical modeling mentioned in the Common Core Standards and in the way modeling is defined by the NGSS. Think of modeling, in its most basic sense, as simply being something that represents and acts like something else. Since we cannot reasonably build and test a full size car body, we built a scale model. Although aerodynamic drag will differ somewhat due to the size of the model, the main thing is the relationship between the drag of the flat wall and the drag induced by the car body, not its size. The numbers should be fairly accurate.

Another example of modeling can be found in the use of constants. The calculations for inertia and rolling resistance both used constant values. The softness of the road surface, for example is modeled with a number. A higher number indicates a softer surface. The coefficient of aerodynamic drag is also a modeling tool. Students familiar with the concept should be able to draw a profile of a car that is nearly 1 or nearly 0.1 with ease. The number models, or represents, the actual object.

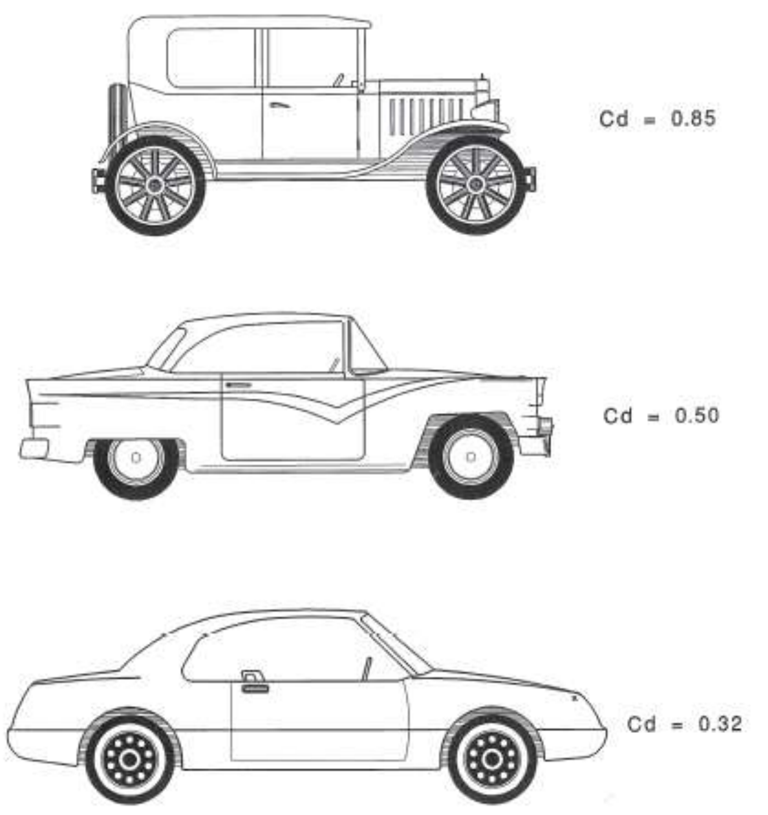


FIGURE 3.12 Declining Aerodynamic Drag of Automobiles

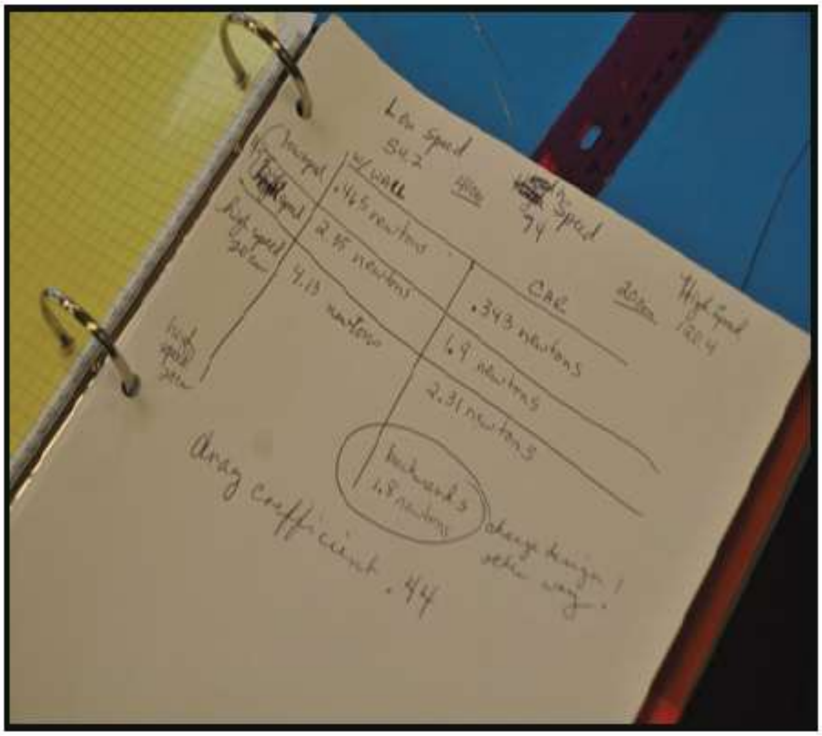
Riley, R.Q. (2004) Alternative cars in the 21st century: a new personal transportation paradigm, second edition, SAE International, Warrendale, PA

You may find the drag coefficient varies depending upon the speed. For the equation, select the speed most appropriate for your car's purpose. Obviously a car designed for 40 mph is never going to experience 100 mph wind drag. Complete the calculations for determining aerodynamic drag.

Record your calculations in Section 3 of the Engineering Journal.

Reflection

Only in artificially contrived story problems do the numbers work out cleanly. When using data gathered by the students, graphs seldom form a nice straight line. We operate in a world of imprecise data influenced by unidentifiable variables. Students must learn that real mathematics is never as "clean" as in the theoretical environment of a text book. In this case, that means to make an argument for the "line of best fit" and critique the reasoning of others. These skills are valuable skills for the 21st century workforce, and clearly identified in both the Common Core and the NGSS.



Putting It All Together:

Calculate the total required motive force for several different scenarios (e.g. maximum acceleration on flat ground, top speed on flat ground, constant speed up a steep hill, etc.). In each case, determine the motor horsepower required to produce the required force using:

$$Horsepower = \frac{FV}{375}$$