Lab Handout

Lab 23. Power: Which Toy Car Has the Engine With the Greatest Horsepower?

Introduction

With the onset of the Industrial Revolution, many people wanted a way to compare the capabilities of new machines with existing ways of doing things. For example, when James Watt started building and selling steam engines in the late 18th century, one of his customers asked Watt to compare the power of the engine with the power of a horse. The customer, in other words, wanted to know if the new steam engine could do the same things a horse could do. Watt used the term *horsepower* as a convenient way of comparing the power of his steam engine with the power of a horse. Figure L23.1 shows a painting by Carl Rakeman of a race in 1830 between a horse-drawn cart and the first steam locomotive built in the United States, which was called Tom Thumb. This race was an important event leading to the rise of the railroad industry in America because it demonstrated that a steam-powered locomotive could outperform a horse. Since then, *horsepower* has been given a formal definition as a unit of measure, with 1 horsepower (hp) equal to 746 watts (W).

FIGURE L23.1

Painting by Carl Rakeman of the Tom Thumb steam-powered locomotive racing a horse

Note: A full-color, high-resolution version of this image is available on the book's Extras page at *www.nsta.org/adi-physics1*.

Although most countries use the watt or kilowatt as the standard unit of power, in the United States horsepower is still quite common. Most devices that are powered by an engine or motor are advertised based upon their horsepower; these include household devices such as blenders, lawnmowers, and electric garage door openers. The most common use for horsepower is to describe the power of a car engine. Most everyday cars have an engine of approximately 150 hp, but the fastest sports cars can have engines that are up to 600 hp. And race cars can have engines that are over 800 hp.

An independent group must verify the advertised horsepower of a new engine before a company can sell that engine or a vehicle with that engine in it. An independent group can use several different methods to measure the horsepower of an engine that they did not build; these methods are based on the conservation of energy and the relationship between work and power. The two most common methods are (1) to measure how long it takes the engine to lift or pull a mass a given distance and (2) to measure the amount of time it takes the car to reach its maximum velocity when starting from rest and then use the work-energy theorem to determine the maximum horsepower of the engine. In this investigation, you will have an opportunity to develop your own method for measuring the horsepower of a toy car's engine using the work-energy theorem.

Your Task

Use what you know about the conservation of energy, the relationship between work and power, systems and system models, and the importance of tracking the flow of energy in a system to develop a method for measuring the horsepower of a toy car engine. You will then test the engines of several different toy cars using your method to determine which one has the greatest horsepower.

The guiding question of this investigation is, ***Which toy car has the engine with the greatest horsepower?***

Materials

You may use any of the following materials during your investigation:

Consumables
- Tape
- String or fishing line

Equipment
- Safety glasses or goggles (required)
- 4 Different types or brands of remote control cars
- Hanging mass set
- Electronic or triple beam balance
- Stopwatches
- Ruler
- Metersticks

If you have access to the following equipment, you may also consider using a video camera and a computer or tablet with video analysis software.

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on-activity, and takedown.
2. Keep fingers and toes out of the way of moving objects.
3. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to create a method that you can use to determine the horsepower of the engine found inside a toy car. This means you will need to determine the maximum power that the engine is able to produce. *Power* is defined as the rate at which work is done on an object. The equation for power is $P = W/t$, where W is work and t is time. The term *work* is used to describe any situation when a force acts on an object over a displacement of that object. For a force to qualify as having done work on an object, there must be a displacement and the force must be either parallel to the displacement (e.g., a force to the right with a displacement to the right) or antiparallel to the displacement (e.g., a force to the right with a displacement to the left). The equation for work is $W = \mathbf{Fd}$, where $\mathbf{F}$ is force and $\mathbf{d}$ is displacement. Finally, and perhaps most important in terms of your goal for this investigation, energy cannot be created or destroyed—it just changes form as objects move or as it transfers from one object to another one. You will need to use these fundamental ideas as the foundation for the method you will develop, but there may also be other ideas that you need to use.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system under study?
- How can you describe the components of the system quantitatively?
- How could you keep track of changes in this system quantitatively?
- Is it useful to track how energy flows into, out of, or within this system?
- How might the structure of the toy car affect its function?
- How might the structure of the test of horsepower affect its function?

To determine *how you will collect the data*, think about the following questions:

- What types of equipment will you need to use and how will you use it?
- How will you track the flow of energy into, out of, and within the system under study?
- What scale or scales should you use when you take your measurements?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What type of calculations will you need to make?
- What types of comparisons will you need to make?

- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

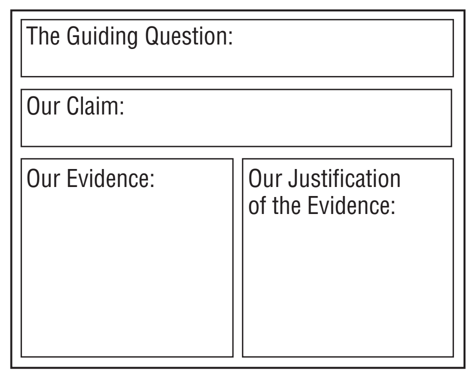
- the difference between observations and inferences in science, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument must include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L23.2.

FIGURE L23.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!