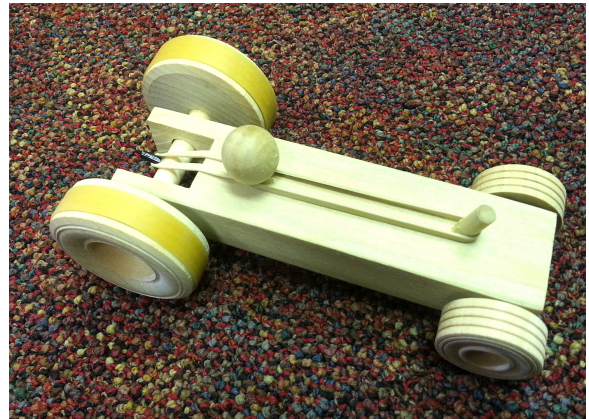


Engineering Design Challenge – Investigation 1

NOTE: Students should have completed the Focus on Energy curriculum prior to working on this challenge.

Plan Investigation 1

In this 2-class Investigation students work on solving a practical problem: How can you use simple materials (supplied kit) to modify a car so that it comes to a stop exactly where you want it to? Students start with a toy car that has enough stored elastic energy to propel itself 12 feet or more. They are challenged to modify the car so that it comes to a stop between 3 feet and 6 feet beyond a starting line. The strategy they are asked to employ is to transform some of the car’s motion energy into thermal energy.



Students are familiar with motion energy, thermal energy, and energy transformation, but have had only one brief experience—in Thermal Investigation 1—that highlighted the transformation of motion energy into thermal energy: they rubbed their hands together and sensed the resulting warmth. That transformation, however, is ubiquitous: all motion energy is accompanied by some degree of friction, and friction transforms motion energy into thermal energy. In Motion Investigation 1, a ball rolling along the track slowed down and stopped moving. The explanation is that while the ball was rolling, friction—between the ball and air, and between the ball and the track—continuously transformed some of the ball’s motion energy into thermal energy until no motion energy remained. The term *friction* (a force), however, is not introduced in this investigation. Discussing friction can get complicated and may detract from the learning goals of this investigation. If students mention friction, that’s fine. Explain that in this investigation we use the term “rubbing”.

In previous Focus on Energy investigations, as students attempted to answer the question, “Where did the energy go?”, they frequently concluded with, “...then energy went into the environment.” That response was often correct, but one goal of this investigation is to help students move past that somewhat vague response to understand that often the “it” that moves into the environment is *thermal energy* transferring to the *air*. Another goal is to reinforce some of the key energy concepts that were highlighted previously—energy forms, energy transfer, and energy transformation—by having students analyze the flow of energy through a new system, one which they will have a role in designing.

In this investigation students work in pairs, using only the limited materials provided in a kit to modify their toy car so that it stops in the target area. As they work, they collect and record data in their Student Notebooks. And as they have done throughout much of the Focus on Energy curriculum, they also tell the energy story.







Allow two class periods for this engineering design challenge: one day for introducing the challenge, the associated concepts, and time for students to develop and test their designs; and a second day to develop and share energy stories. The two class periods should be as close together as possible.

Learning Targets

This engineering design challenge is a context for introducing some ideas about engineering design and reinforcing some important ideas that were introduced in the Focus on Energy units, and specifically some ideas that were introduced in the Thermal Energy unit:

- Motion energy can be transformed into thermal energy through rubbing.
- If an object’s temperature increases or decreases, its thermal energy has increased or decreased.
- Thermal energy can be transferred between objects through contact.

- Some thermal energy of a warm object is transferred to its surrounding environment.
- When thermal energy is transferred to the environment, temperature changes in the environment may be too small to observe.
- Possible solutions to a problem are limited by available materials.
- Different possible solutions to a problem need to be tested in order to determine which of them best solves the problem.

Sequence of Experiences			
1. Introduce the Challenge		All Class	 10 Minutes
2. Motion Energy, Brakes, and Thermal Energy		All Class	 15 Minutes
3. Design Challenge and Clean-Up		Pairs	 35 Minutes

Materials

For the class:

- One propeller–rubber band system (used in Motion 4)
- One bicycle. Either a child–size or adult size will work (not included in kit)
- One digital thermometer (used in Thermal 3)
- 1 tape measure that expands to 15 feet (not included in kit). Alternatively, use 2 yardsticks, or if you have 1–ft square tiles on the classroom floor you can use the tiles for measurement.

For each small group of 2 students:

- 1 wood car with rubber band
- 1 gallon–sized zip lock bag holding:
 - 1 4"x6" kitchen sponge
 - 2 6" paper plates
 - 1 piece of string (3 ft.)
 - 4 plastic straws
 - 1 roll Scotch tape
- Scissors (not included in kit)

For each student:

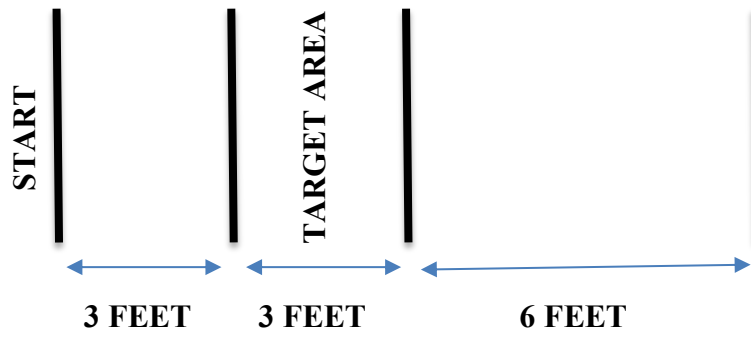
- Engineering Design Challenge student notebook (Available on web site)

Preparation:

- Read the document "Background Information" in the Appendix.
- Practice setting up, spinning, and stopping the bicycle wheel as described in Part 2. Use the FRONT wheel and spin it with your hand.
- Assign teams of two to work together on the challenge.
- (Optional) Prepare to take a photo of each design.
- Create 2 or 3 Test Tracks on the classroom floor or other available space. For each Test Track, use four 18–inch–long pieces of masking tape to establish four lines: 1) a Starting Line; 2) a line 3 feet from the starting line; 3) a line 3 feet after that line; and 4) a line 6 feet after that line. The area between 3 and 6 feet is the target destination for the redesigned cars. See Test Track Layout below.

NOTE: If you have a smooth (tile, etc.) floor in the area of the test tracks, be sure it is free of the sand and dirt that shoes may track into the classroom. Car wheels will just spin on a gritty floor! Smooth floors must be clean in order for the drive wheels of the cars to properly grip the floor surface.

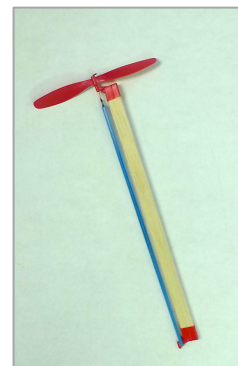
TEST TRACK LAYOUT



1. Introduce the Challenge

All class – 10 Minutes

Gather students in a circle. Ask if they remember using the propeller–rubber band system, and demonstrate by winding and releasing the propeller. Ask if they remember the energy story of that system. Students may recall the *transformation* from elastic energy to motion energy of the rubber band, the *transfer* of motion energy from the rubber band to the propeller, and possibly the *transfer* of motion energy from the propeller to the air.

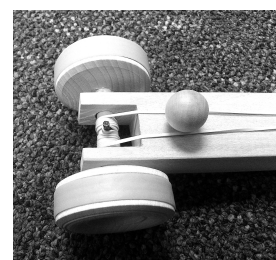


Explain that today students will work like engineers, to solve a problem. Today's problem involves elastic energy and motion energy, and thermal energy as well. They will use their ideas about energy to help them solve the engineering problem. This time the object they will work with is not a propeller; it's a toy car.

Holding a wooden car vertically with one hand gripping the smaller front wheels, rotate the large rear wheels to wind the rubber band around the axle a few times. Then release the rear wheels so they spin in the air, mimicking the way the propeller spins when holding the balsa stick.

Ask if someone can tell the energy story of the rubber band beginning when it was tightly wound until it was no longer stretched.

Now show how to wind rotate the wheels six full times, winding or stretching (deforming) the rubber band. This time place the car on the floor and let it go. How far did the car travel?



If I rotate the big wheels six full times, the car will travel 12 feet or more.

Introduce the challenge.

Your challenge is to make changes to the car so that even after winding the rubber band six times around the axle, the car will only travel between three and six feet instead of twelve (or more) feet.

What are some of your ideas about how to stop or slow down a bike or sled or car or other moving vehicle?

Listen for ideas. They might include brakes, speed bumps, or adding weights to the car.

Acknowledge students' ideas. It is likely someone has suggested some kind of brake.

Today we're going to talk about one of your suggestions: brakes.

2. Motion Energy, Brakes, and Thermal Energy

All class – 20 Minutes

Discussion about brakes

If you were small enough, and if you had brakes for this toy car, you could ride on it and use the brakes to make it stop somewhere between 3 feet and 6 feet.

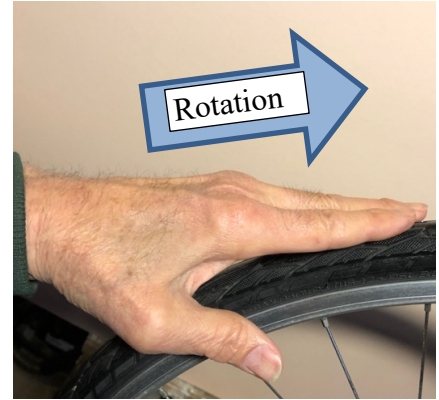
Does anyone know how brakes actually work?

How do brakes cause a bicycle to stop?

Listen to student ideas about how brakes work. Some will know that many bicycle brakes work by squeezing the wheels. If the topic comes up, agree that car brakes are more complicated but that rubbing against a moving part of the wheel is also what stops the car, the same approach as stopping a bicycle.

Demonstrations

Have students assist you in holding the upside-down bicycle while you spin the wheel *away* from you. Then, demonstrate a simplified version of how bicycle brakes work by lightly pressing fingers against the rubber, causing the wheel to slow down and stop. (See image.)



Think about the energy story. What kind of energy did the spinning wheel have?

→ Motion energy.

Do you agree that the wheel lost motion energy after I made it rub against my finger?

→ Yes.

When the wheel lost motion energy, what gained energy?

Listen to student ideas without making judgements, even though they may switch from a focus on energy to a focus on mechanism, explaining that it was your finger that made the wheel stop.

Move on to the next demonstration, which highlights the transformation of motion energy into thermal energy.

Have another student assistant come up to observe and report on the thermometer's temperature. Then spin the wheel again, this time using the shaft of the thermometer (in place of your finger) to apply gentle pressure against the rubber tire. (See image.) The temperature reading on the thermometer—which indicates the temperature of the shaft of the thermometer, which in turn indicates the temperature of its immediate environment—will increase by 5 degrees F or more. As the wheel stopped spinning, motion energy transformed into thermal energy.



Debrief the demonstration

Repeat the question:

When the wheel lost motion energy, what gained energy? What is the evidence?

Students are likely to say the thermometer (casing) gained thermal energy (true). They may respond that the wheel also gained thermal energy and back up this claim by saying the wheel felt warmer as it slowed down.

The important point to highlight is: when something rubs against the wheel, *motion energy is transformed into thermal energy*. In general, when things rub against each other, motion energy gets transformed into thermal energy. That's what bicycle brakes do.

Can you think of another example from everyday life where motion energy transforms to thermal energy?

Responses will provide insight into your students' experience. Examples might include:

- A saw blade gets warm as you cut wood.
- The kitchen mixer gets warm as the beaters spin.
- A car's tires get hot as it skids to a stop.
- You get a "floor burn" as you skid across a gym floor or down a slide.
- An eraser gets warm as you rub it vigorously across a surface.

Do you remember rubbing your hands together in Thermal Investigation 1 and feeling your hands get warmer? That's another example of motion energy being transformed into thermal energy by rubbing.

Note: If hands did not appear to lose motion energy as they gained thermal energy, it is because the body was continuously transferring (or losing) chemical energy to the hands to keep them moving.

Your challenge is to make changes to the car to transform enough motion energy of the car to thermal energy so that, even after winding the rubber band six times around the axle, the car only travels between three and six feet instead of twelve feet. There are different ways to do this, but everyone must use rubbing to transform motion energy into thermal energy.

3. Design Challenge and Clean-Up

Pairs – 35 min

Instructions

Show students the packet of materials they have to work with. They should use nothing but the materials in the bag (or the bag itself) to make their braking system.

Emphasize that students should take time to discuss different ideas with their partner *before* they decide on a plan and start to change the car in some way. This is a challenge for two people to work on. Engineers often work in teams to discuss plans before they start working on a new design.

Their solution must transform motion energy into thermal energy by rubbing—even though the amount of thermal energy will be tiny and we will not be able to measure it with a thermometer.

Students should use one of the test tracks to test their design. The car’s front wheels must stop in between the 3-foot line and the 6-foot line to be a successful design.

Your design should work more than once. If it can't stop the car in the target area two or three times in a row, it's not yet a reliable design.

You probably will not solve the problem the first few times you try. That's OK, but you should write the results of each test in your student notebooks. Collecting and analyzing data is very important to engineers and scientists.

Distribute student notebooks and review the pertinent pages with the class.

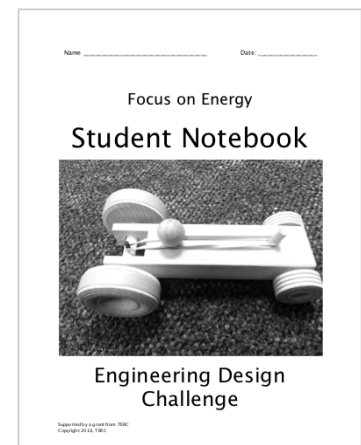
Contents includes:

- Page 2: The Energy Tracking Lens
- Page 3: How to properly wind up the wooden car
- Page 4: Completing, measuring, and recording results of a Test Run before working on the brakes
- Page 5: Places to record the result of every test with brakes. Students are unlikely to run 8 tests. There is also a place to *measure and record* the final test of the day.

Page 6 (and page 7 if needed) is for use in Day 2.

*You will have the rest of the class to work on solving the problem.
You will have time in the next science class—or later today if you finish early—to use energy cubes to tell the energy story.*

Distribute cars and a bag of materials to each pair.



Note: If a pair seems stuck, offer help. Solving the challenge independently is not the main goal; it is just the context for strengthening ideas about the transformation of motion energy to thermal energy, the transfer of that energy into the air, and the concept that change can be too small to sense.

If a team addresses the challenge quickly, suggest they tackle a new challenge: Make the car stop between 6 ft and 8 ft.