

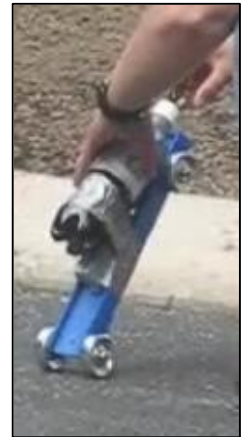


# Motion and Collisions

## 2007 SPS Outreach Catalyst Kit

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## Welcome

Dear SOCK Recipient,

We would like to congratulate you and your chapter for taking part in the **SPS Outreach Catalyst Kit** program. As the name implies, the SOCK is meant to be a catalyst for outreach by your chapter - it's meant to give your chapter ideas and materials for beginning or expanding a physics outreach program. We have put together this kit to help you along your way to outreach fun and excitement during the year.

This manual includes step-by-step instructions for putting on an outreach event using what we call "Adaptive Lesson Plans." The lessons are primarily geared for middle school students. However, we include suggestions for adjusting the complexity of the lessons for other audiences. Key features of this manual include:

- Step-by-step lesson plans including,
  - Suggestions and alternate experiments for different audiences;
  - Ways to decompose lessons into individual demonstrations and experiments; and
  - Time estimates for preparation and execution.
- Complete explanations of the construction, setup, and use of all equipment.
- Suggested topics for post-lesson discussion.
- A list of additional resources.

Your SOCK also includes a resource CD that has supplemental information, as well as some videos related to the activities.

The theme for the 2007 SOCK is *motion and collisions*. Our lessons cover a variety of practical applications in these areas including seatbelt safety, rocket launching, and satellite orbits.

We encourage your chapter to experiment with the lessons and materials included in the SOCK. Please note that these lessons are only a starting point and you are free to modify the activities and worksheets - we hope that you find numerous uses for the SOCK within your chapter and your community.

SPS National and the 2007 Summer SPS SOCK interns thank you for taking part in this project. Have fun! If you have any questions or comments please feel free to contact us.

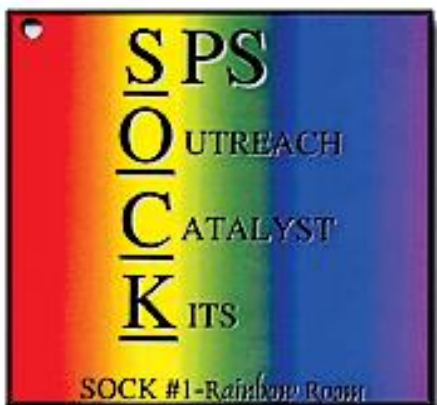
Sincerely,

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For more information on the SOCK, visit [www.spsnational.org/programs/socks](http://www.spsnational.org/programs/socks).

## History of the SOCK



The SPS Outreach Catalyst Kit (SOCK) program began in 2001 as part of an outreach effort by the national office of the Society of Physics Students (SPS). The program aims to help SPS chapters reach out to their local communities and stimulate interest in physics.

The first SOCK was created by SPS intern Mark Lentz (Northwestern State University) in 2001. The SOCK, *Rainbow Suite*, sought to teach the properties of rainbows. This started the legacy of light demonstrations that have been present in every SOCK.

The 2002 SOCK was put together by SPS interns Lauren Glas (Rhodes College) and Jason Tabeling (Virginia Tech). *Dimensions in Physics* explored geometry in a variety of settings.

The 2003 SOCK was constructed by SPS interns Stacey Sude (Northern Virginia Community College) and Ashley Smith (McGill University). *Spanning Space* included the popular light elements, and brought in the first large-scale experimental component with a nation-wide cylinder dropping experiment.

The 2005 SOCK was a joint effort of the 2004 SPS interns Heather Lunn (University of Wisconsin - River Falls) and Matthew Shanks (Rhodes College) and the 2005 SPS interns Morgan Halfhill (Austin Peay State University) and Rebecca Keith (Drew University,). Entitled *The World Year of Physics 2005*, it was part of the worldwide World Year of Physics celebration. This sock added a new twist to the ever-popular light elements and included a special lesson to commemorate Einstein's 1905 discoveries with an experiment to measure the speed of light.

The 2006 SOCK was constructed by Katherine Zaunbrecher (University of Louisiana) and Jackie Michalek (California University of Pennsylvania). Its theme centered on the effects of temperature and it coincided with the *Absolute Zero and the Conquest of Cold* campaign.

This year's SOCK was constructed around motion and collisions and has a variety of lessons in these areas, including experiments featuring the ever popular Diet Coke and Mentos reaction.

The SOCK project is supported by the Society of Physics Students (SPS) and its associated honor society, Sigma Pi Sigma. SPS is the professional society for physics students and their mentors. It operates within the American Institute of Physics (AIP), an umbrella organization for ten other professional societies.

For more information on SPS, please visit [www.spsnational.org](http://www.spsnational.org).

## Planning an Outreach Program

There are many different kinds of science outreach you can do within your local community, such as,

- Performing science shows or demonstrations for local schools,
- Holding workshops or demonstrations for youth clubs,
- Hosting a table during the visit day or open house at your school, and
- Participating in tutoring or mentoring programs.

If you would like to start a new outreach effort, you might consider following these steps.

1. Determine the amount of time you and your chapter are willing to commit to an outreach event, and what type of event you would like to hold.
2. Find your audience. You might,
  - a. Contact your chapter's advisor and other faculty members in your physics and education departments to find out about existing outreach programs.
  - b. Contact the math, science, and technology teachers at local school districts and let them know you are interested in putting on events for their students.
  - c. Contact local youth organizations such as the Boy/Girl Scouts of America, 4H, YMCA, etc. to see if they have an interest in participating.
3. Schedule the event and get all the specifics - a contact person, the number of students expected, their grade level, time constraints, and what the location is like (Can you go outside? Is there equipment available for use?).
4. Research the topics and adapt the lesson plans in the SOCK for your event.
5. Practice explaining and demonstrating the concepts you intend to cover.
6. Verify that the logistics are ready the day before your event.
7. Do a post-evaluation of your outreach event to assess how things went and what could be improved for future programs.

SPS's primary goal for the SOCK is to encourage students to continue exploring the universe around them. This kit is intended to provide chapters with ideas for physics projects and demonstrations that they can do with members of their community.

As the name suggests, the kit is meant to serve as a catalyst, prodding your chapter to reach out to local schools and community members. You may need to supplement the materials in this SOCK in order to engage students effectively - for example, you might need multiple set-ups of an experiment if you are working with a large group. Therefore, we have included information on vendors (page 39) and instructions for constructing the pieces (page 35-38). Have fun!

## National Science Education Standards

If you talk to teachers about visiting their classrooms, you might be asked how your demonstrations fit in with their science standards. While each state defines its own standards, most are based on the National Science Education Standards, published in 1996 by the National Academy of Sciences (<http://www.nap.edu/catalog/4962.html#toc>). These standards cover the topics and skills that K-12 students should know at different stages of their education.

The general physical science content topics for each grade level are given below. Note that all include references to concepts that are emphasized in the SOCK (motion and forces, light, transfer of energy, etc.).

*As a result of the activities in grades K-4, all students should develop an understanding of*

- \* *Properties of objects and materials*
- \* *Position and motion of objects*
- \* *Light, heat, electricity, and magnetism*

*As a result of their activities in grades 5-8, all students should develop an understanding of*

- \* *Properties and changes of properties in matter*
- \* *Motions and forces*
- \* *Transfer of energy*

*As a result of their activities in grades 9-12, all students should develop an understanding of*

- \* *Structure of atoms*
- \* *Structure and properties of matter*
- \* *Motions and forces*
- \* *Conservation of energy and increase in disorder*
- \* *Interactions of energy and matter*

In addition, the standards require that students understand the process of science, are able to use math to interpret results, graph data, communicate their results, etc. The hands-on activities in the SOCK are designed to help students build these skills as well.

# SOCK Contents

Dynamics Cart		0.5 L Diet Coke	
Seat Attachment		1 Pack of Mentos Mint Candies	
Play-Doh		1 Propping Block	
Cookie Cutter		1 Starting Cap	
Hot Wheels Radar Gun w/ Batteries		1 Super Slingshot	
Diffraction Glasses (25)		Resource CD	
Supplemental Worksheets			

If any of these items are missing from your SOCK, please contact the SPS National Office at [sps@aip.org](mailto:sps@aip.org) or (301) 209-3007.

## Lesson 1: Crash Test Smarties

In this activity students will explore motion and collisions through experiments involving a cart traveling down a ramp. They will determine the relationship between the height of the ramp and the maximum speed of the cart, and then explore how seatbelts work by assessing damage to Play-Doh people riding in the cart under different seatbelt arrangements.

### Objectives

- Students will be able to describe the relationship between the starting height and the maximum speed of a cart traveling down a ramp.
- Students will be able to assess the amount of damage to a crash test dummy and draw conclusions regarding the safety of different seatbelt arrangements.

### Topics

- Conversion of potential energy to kinetic energy.
- Collisions and transfer of momentum.
- Seatbelt safety.

### Materials

(Items in red are included with this kit.)

- Hot Wheels radar gun
- Dynamics cart
- Seat attachment
- Play-Doh
- Cookie cutter
- Supplemental worksheet (optional)
- Long board to use as a ramp (16 x 12 x 10 works well)
- 4 large boxes that can be used to adjust the height of the ramp
- Heavy board (or nearby wall)
- Small piece of wood or thick cardboard (see Advanced Preparation, step 3)
- Graph paper (optional)

### Advance Preparation

Estimated time: 2 hours

1. Connect the seat attachment to the cart, if it is not already attached.
2. Draw a line across the board you are using for the ramp, about one foot from one end. This will be used to indicate where the board should rest on the top box, which is important for consistency between trials. See Figure 2, A.
3. Attach the small piece of wood or cardboard to the back of the ramp, forming a lip (Figure 2, B). This should be used to align the rear wheels of the dynamics cart before each run, helping it travel in a straight line.



Figure 1 - Seat attachment on cart.



Figure 2 ó The ramp setup. A) Line used to align ramp with boxes. B) Wooden lip to align wheels of dynamics cart.

4. Draw two graphs on large sheets of paper. One graph should have "Hot Wheels speed" on the y-axis and "Number of boxes" (or, for high school students, "Height of the ramp") on the x-axis. The other should be a three dataset bar graph with "Damage" on the y-axis and the "Trial" and "Seat Position" on the x-axis.

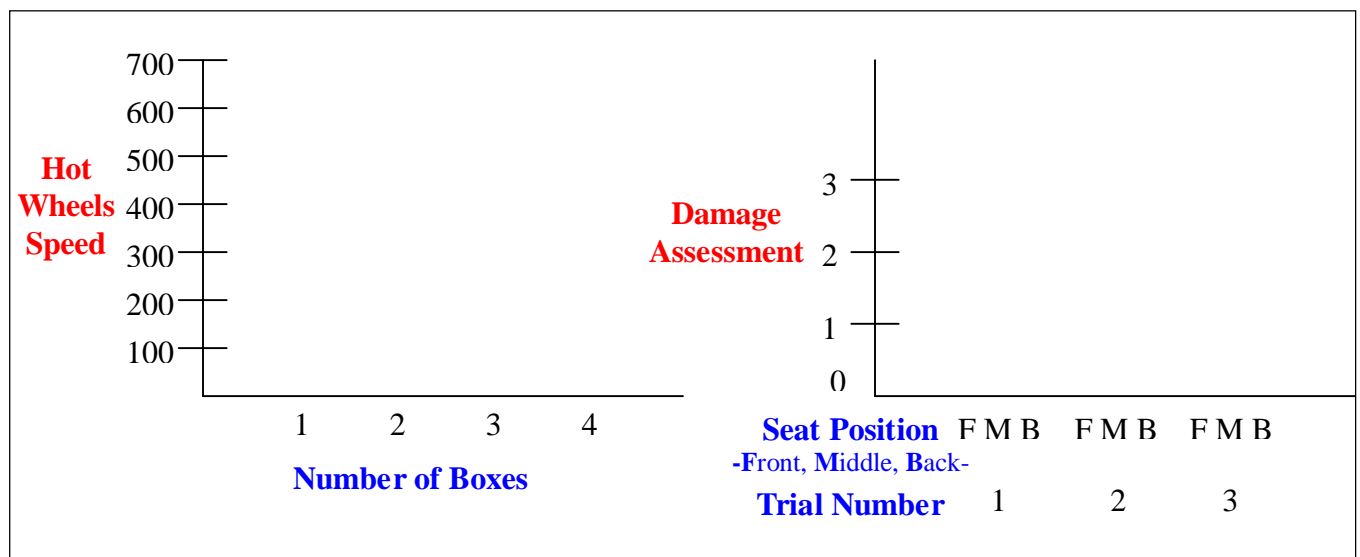


Figure 3 ó Graphs for collecting and displaying data.

5. If you can access the area where the activity will occur ahead of time, taking care of the following items will make the activity run more smoothly.

- Clear a large open area for the ramp.
- Set the ramp to a height of 1 box.
- Set the Hot Wheels radar gun to "Hot Wheels Speed" and mph.
- Flatten the Play-Doh to be used by students for cutting out crash test people.
- Test the seatbelt straps for tightness.

## Conducting the Activity

Estimated time: 45 minutes

### 1. Introduce the topic

This activity explores the relationship between the height of a ramp and the highest speed that a cart traveling down the ramp will reach. You might use the students' previous experiences with roller coasters and amusement parks as one way to highlight the concept. Another connection can be made to riding a bicycle down a hill - the size of the hill affects the speed that the bicycle will reach.

### 2. Explain how to use the Hot Wheels radar gun

If you point the gun at an object and hold down the trigger, the gun will continuously record the speed of the object. When the trigger is released, the maximum speed of the object is displayed. The students should keep the dial settings on  $\text{mph}$  and the Hot Wheels logo. Note that the radar gun measures speed in *Hot Wheels mph*, where the ratio of Hot Wheels mph to actual mph is 64:1.

### 3. Have students practice using the radar gun

Have a few students walk side-by-side at the same speed in the same direction, while another student uses the radar gun to measure their speed, as shown in Figure 4. Have all of the students try this until they are comfortable operating the radar gun.



Figure 4 - Hot Wheels radar gun demonstration.

### 4. Prepare for the speed vs. height experiment

Divide the students into pairs. Once the students have been divided into pairs, give each pair a letter, A-D. This letter will determine where they start in the task rotation described below. If there are more than four pairs, simply add a break period between two tasks for students to make observations about the activity

- A. This pair releases the cart from the top of the ramp and measures its maximum speed.
- B. This pair records the outcome of the trial on the chart.
- C. This pair adjusts the boxes before the next run.
- D. This pair catches the cart to ensure that it does not hit the person holding the radar gun.

### 5. Carry out the speed vs. height experiment

Place the board on top of one of the boxes and make sure it is aligned properly (step 2 under "Advance Preparation").

Have a student from Pair A lay on the ground and point the radar gun directly at the bottom of the ramp, parallel to the ground, as shown in Figure 5.

Have the other student from Pair A align the cart using the lip at the top of the ramp (step 3 under "Advance Preparation"). When everyone is ready, the student should release the cart.

Have the pairs rotate tasks and then repeat the activity for different ramp heights, until every set of pairs has done each case. After they are finished, regroup the students for a discussion.

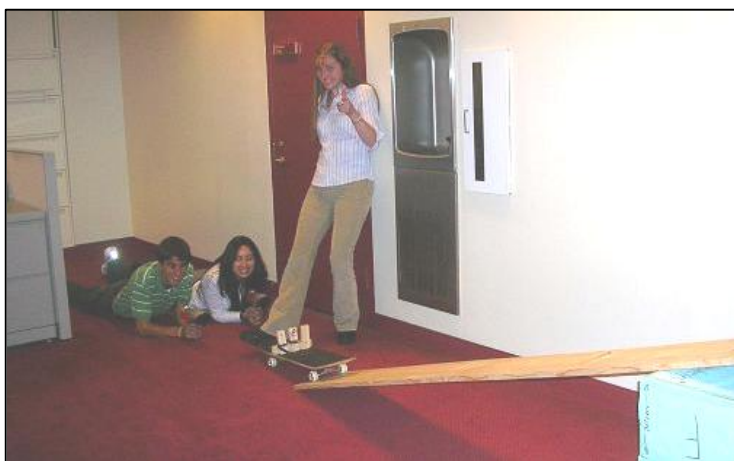


Figure 5 - The ramp setup.

### 6. Group discussion on the speed vs. height experiment

The data should demonstrate that as the height of the ramp increases, the maximum speed the cart reaches increases as well (this relationship follows the relationship  $mgh = \frac{1}{2}mv^2$ , but keep the discussion qualitative unless working with advanced or high school students).

In addition to discussing the physics that is demonstrated with this experiment, also discuss the importance of having multiple trials and comparing data. If there is time, a discussion about errors can be meaningful at this point.

### 7. Prepare for the damage analysis experiment

Each student should each make his or her own Play-Doh person, using the mold included in the SOCK. These will be used as "crash test smarties" for the experiment. After students make their people, have them place their Play-Doh figures on a desk or table near the ramp to avoid damaging them while waiting for their trial.

Adjust the ramp system so that there is a heavy board or wall at the end of the ramp, as shown in Figure 6.

The students will take turns strapping the Play-Doh people into the carts, releasing the cart, and adjusting the height of the ramp. Students should rotate through the tasks described below.

- A. Strap the Play-Doh people into cart (3 Play-Doh people should go at once).
- B. Release the cart.
- C. Adjust the height of the ramp.
- D. Hold the board at the end of the ramp (if necessary).



Figure 6 - The ramp setup and roles for students during the experiment.

### 8. Carry out the damage analysis experiment

Have 3 students load their Play-Doh people in the cart. The Play-Doh person on the front seat should have no seatbelt on, the person in the second seat should have only a lap belt, and the person in the last seat should have a shoulder belt and a lap belt. Then a student should release the cart from the top of the ramp.

After each trial, every student should record his or her own rating of the damage inflicted on each Play-Doh person due to the collision. The rating scale is:

- 0 - There is no evidence of damage.
- 1 - There is slight damage, but the person would probably walk away from the crash.
- 2 - There is significant damage to the person, likely requiring a trip to the hospital.
- 3 - The person was thrown from the car or hurt so badly that he or she might not live.



Figure 7 ó The Play-Doh people all ready for a ride

The students should rotate tasks until each one has participated in at least one trial.

### 9. Group discussion on damage analysis

This discussion should be targeted towards seatbelt use and design. The students should talk about which Play-Doh people had the worst injuries and which had the most minor injuries. If there is time, make a connection between the speed and damage to the person by combining this data set with the data set from the speed vs. height experiment.

### Extensions

This is a good activity for any age group since people of all ages tend to dislike wearing seatbelts. However, the analysis will be too easy for most high school physics students. Suggestions are given below on how to challenge these students and connect the activity to the concepts they are learning in class.

- In the first activity, have students measure the height of each ramp and use conservation of energy to predict a maximum velocity for the cart. This will require measuring the mass of the cart system. The predicted value will be greater than the actual value because this analysis neglects friction and the kinetic energy of the rolling wheels. In addition, some energy is lost in the cart's collision with the floor.
- Have the students convert the Hot Wheels mph to m/s (using the 64:1 ratio of Hot Wheels mph to actual mph and the conversion from mph to m/s).
- Have the students discuss errors in the experiment and, in particular, how important statistical relevance is in experimental physics work.
- Use the activity to prompt a discussion on the conversion of energy.

### Reflection

For students of any age, a meaningful journal prompt might involve something about the connection between physics and how the student's view of the world has been altered or reinforced through the activity. For example, "How has this activity affected the way you think about your seatbelt?"

### Assessment

An assessment of student understanding should be based on the data and responses given on the worksheet, in addition to discussion participation.

### Additional Resources

Hyperphysics Website, hosted by Georgia State University Department of Physics and Astronomy

"Seatbelts" <http://hyperphysics.phy-astr.gsu.edu/hbase/seatb.html#cc1>

"Car Crash Example" <http://hyperphysics.phy-astr.gsu.edu/hbase/carcr.html#cc1>

Sample of the corresponding worksheet. See folder pocket for master copy.

# Speed

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Today we're going to learn a few things about car crashes, and how your speed and seatbelt affect your safety.

We will measure speed with Hot Wheels radar guns. Your gun should be set to the Hot Wheels speed setting (this speed is 64 times the speed in real miles per hour.)

What is the Hot Wheels speed of someone walking? \_\_\_\_\_

### Speed of Cart vs. Height of the ramp

1. Record the data your group collects below. Also make sure that this data is added to the class graph.

Height of Ramp:	1 Box	2 Boxes	3 Boxes	4 Boxes
HW Speed				

- In which case did the cart travel the fastest?
- As the height of the ramp increases, how does the speed of the cart change?

Is this what you expected? Why or why not?

### Crash Test Smarties

Use the following scale to judge how badly the Play-Doh people are damaged after each accident. Enter the numbers in the chart below.

0 - There is no damage to the person.

1 - There is slight damage to the person, but he or she could probably walk away from the crash.

2 - There is significant damage to the person. He or she would probably go to the hospital.

3 - The person was thrown from the car or hurt so badly that he or she might not live.

	1 Box	2 Boxes	3 Boxes	4 Boxes
<b>No seatbelt</b>				
<b>Seatbelt at waist only</b>				
<b>Seatbelt and shoulder belt</b>				

3. What does this tell you about seatbelts?

4. Do you think it would better to be in a 1-box ramp crash with no seatbelt, or a 4-box ramp crash with a seatbelt and shoulder belt?

Why do you think so?

If you have time, try this experiment.

## Lesson 2: Diet Coke & Mentos Car

This lesson utilizes a recently discovered, and widely spread via the internet, phenomenon that occurs when Mentos are added to Diet Coke. There are several theories about why Diet Coke and Mentos produce such a dramatic reaction. According to Bob Becker in the February 2007 issue of ChemMatters, published by the American Chemical Society (ACS), the reaction is thought to be primarily a physical reaction between the carbon dioxide in the Coke and the surface of the Mentos. A copy of this article is included in the SOCK, with the permission of ACS.

### Objectives

- Students will be able to use the scientific method to optimize the reaction between soda and candy.
- Students will be able to design an optimized soda and candy-propelled vehicle, based on their observations.

### Topics

- Energy and energy conversion.
- Newton's Laws of motion.
  - 1<sup>st</sup> Law ó Inertia.
  - 2<sup>nd</sup> Law ó  $F=ma$
  - 3<sup>rd</sup> Law ó Equal and opposite forces.
- Scientific method.
- Engineering design process.

### Materials

(Items in red are included with this kit.)

- **Dynamics Cart**
- **0.5-L bottle of Diet Coke**
- **1 pack of Mentos mint candies**
- **1 propping block**
- **1 starter cap (bottle cap, nail, and binder clip)**
- **Worksheet** (optional)

### *Soda Type Experiment:*

- Five 2-L bottles of various sodas - one should be Diet Coke
- 10 Mentos mint candies
- 5 starter caps (reusable)
- 1 multiple starter system (reusable)
- Digital camera and/or video recorder with tripod (optional)

*Candy Type:*

- Five 2-L bottles of Diet Coke
- 2 Mentos mint candies
- 2 Salt Tablets
- 2 Wint-O-Green Lifesavers
- 2 Sprees
- 2 Mentos fruit candies
- 5 starter caps (reusable)
- 1 multiple starter system (reusable)
- Digital camera and/or video recorder with tripod (optional)

*Optimal Number:*

- Five 2-L bottles of Diet Coke
- 6 Mentos mint candies
- 3 starter caps (reusable)
- 1 multiple starter system (reusable)
- Digital camera and/or video recorder with tripod(optional)

*Nozzle Size:*

- Five 2-L bottles of Diet Coke
- Two 0.5-L bottles of Diet Coke
- 14 Mentos mint candies
- 5 starter caps, each with a different size hole (suggested sizes: 1/4ö, 3/16ö, 11/64ö, 9/64ö, and 1/8ö)
- 1 multiple starter system (reusable)
- Digital camera and/or video recorder with tripod (optional)

*Fuel Load:*

- 2-L bottle of Diet Coke
- 1-L bottle of Diet Coke
- 0.5-L bottle of Diet Coke
- 6 Mentos mint candies
- 3 starter caps (reusable)

**Advance Preparation**

Estimated time: 2 hours

1. Assemble 5 starter caps and one multiple starter system, as outlined on pages 36-37.
2. Be sure you have an open, **outdoor** space to perform the experiments! It's also a good idea to practice using the multiple starter system before doing the experiments with a group.
3. If you are using a camera and tripod to record the experiment, set it up so that the viewing window includes enough space to see the tops of the streams.

## Conducting the activity

Estimated time: 1.5 hours

### 1. Introduce the topic

Explain to the students that in this activity they will design a soft drink and candy-propelled car. Their mission is to optimize the car for traveling across land. Students should use the results of the experiments to determine the best possible design.

### 2. Explain the set-up

Take students through the set-up so they have a sense of how the candy is released into the soda bottles and what they can expect to happen.

### 3. Take students through the initial design process

Once students understand their objective, lead a discussion about which arrangements will create the best car. Have each person write down his or her prediction on the worksheet.

### 4. Carry out the Soda Type experiment

In this experiment, the group will test which type of carbonated beverage will produce the highest stream of fluid when Mentos are added to the soda.

Unscrew the caps from the soft drink bottles and screw on the starter caps. Make sure that the binder clips do not slip from the nails while you are loading starter caps.

When everyone is ready to observe the event, two people should **synchronously** lift the multiple starter system upwards and then back to release the Mentos. (Be careful not to drop the starter stick on the bottles of soda in all of the excitement!). The SOCK resource CD includes videos of this process, and we recommend watching them before performing the experiment yourself.



Figure 1 – Using the multiple starter system. Note that in this case we used 10 bottles for a demo. For experimental purposes, 5 bottles works best.



Figure 2 – Observing the Mentos reaction with various brands of sodas. Notice how the various brands of sodas yield various stream heights.

Give students a moment to record their results on the datasheet and then have a class discussion to determine which type of soda most people think did the best.

### 5. Carry out the *Candy Type* experiment

In this experiment, the group will investigate whether there are candies that will produce a stronger reaction than Mentos when introduced into Diet Coke.

The procedure for the experiment is the same as the *soda type* test. Use the multiple starter system to fire all of the bottles at once, and have the students make observations about the highest stream of soda.

Give students a moment to record their results on the datasheet and then have a class discussion to determine which candy most people think did the best.

### 6. Carry out the *Optimal Number* experiment

In this experiment, students will test how the number of Mentos affects the outcome of the soda fountain.

Prepare 3 starter caps so that one has 1 Mentos, one has 2 Mentos, and one has 3 Mentos on it. Once you have prepared all of the caps, the reactions should be started in the same manner as the previous experiments. Again, have students observe which system yields the highest stream.

Give students a moment to record their results on the datasheet and then have a class discussion to determine which system most people think did the best.

### 7. Carry out the *Nozzle Size* experiment

Now that you have determined the best reactants to use to power the car, tell the students that it's time to determine how to get the maximum travel distance. There are two factors that weigh into the propulsion of the car that are related to the size of the hole in the nozzle. One is the mass flow rate and the other is the exit velocity (remember  $p = mv$ ). For this part of the test, use 5 caps, each with a different size hole. Use 2 Mentos to initiate the reaction and start them simultaneously.



Figure 3 ó Picture of bottle caps with various sized holes drilled into them for nozzle optimization test.

The students should look for the highest two streams of soda for this experiment, which should then be tested against one another to determine which one truly optimizes the mass rate AND the velocity (the height of the stream is primarily a function of the exit velocity).

Give students a moment to record their results on the datasheet and then have a class discussion to determine which systems most people think did the best.

### 8. Try the nozzles on the rocket cars

After the top two nozzles are chosen, use them as nozzles for two 0.5 liter Diet Coke rocket cars powered by 2 Mentos. The car that travels the farthest distance has the optimized nozzle for the car.

To make a rocket car, duct tape the propping block to the middle of the dynamics cart. Then, duct tape the bottle of Diet Coke around the cart so that the cap is pointing downward off the end of the cart, as shown in Figure 4. Hold the bottle upright, replace the regular cap with a starting cap, and pull off the binder clip while holding the bottle upright (see Figure 5). Immediately let the cart fall onto its wheels.



Figure 4 - Side view of a rocket car.



Figure 5 ó Preparing to launch the rocket car.



Figure 6 ó Pacing out the distance traveled by a 0.5 L rocket car.

### 9. Carry out the *Fuel Load* experiment

The final part of this activity is to determine which size bottle should be used to maximize the distance that the car will travel. Use the optimal nozzle that was selected in the previous experiments with a 0.5, 1.0, and 2.0 liter bottle of Diet Coke, and two Mentos.

Start each bottle individually and measure and record the distance that each car travels. After all three trials, compare the different bottle arrangements and select the best cart. This is the optimized Diet Coke and Mentos powered car.

### 10. Final discussion

In addition to the design aspect, this lesson provides a means through which you can discuss Newton's Laws of Motion and their importance to rocketry. The first two are emphasized by the *Fuel load test* and the last law is the fundamental principle behind rocketry. As a refresher, they are (in simple terms):

- Newton's First Law -- objects at rest stay at rest unless acted upon by an outside force.
- Newton's Second Law -- the more mass an object has, the more we have to push to make it move.
- Newton's Third Law -- for every action, there is an equal and opposite reaction.

Another opportunity for discussion surrounds the order in which the experiments were performed. Which experiment should come first ó *Fuel Load* or *Optimal Number? Nozzle size* or *Fuel Load*? Are there other experiments that would help with the optimization process?

### Extensions

- For older students, this activity can be modified to a small group design activity. Perform the nozzle size and bottle size demonstrations for the whole class and then have each group decide which pieces to use to assemble their car. Let them determine variables like the angle of the bottle, and then have each group test their car.
- A great way to supplement this activity is to focus on Newton's Laws. Demonstrations on topics like inertia or equal and opposite forces are appropriate. Here are a few examples:
  - Quickly pull a table cloth out from underneath a plate, glass, and silverware. The dishware should all remain in the same place. This demonstrates Newton's 1<sup>st</sup> Law. Be sure to use dishes that aren't too valuable in case you mess up!
  - Imagine a 3-year old and a 10-year old are sitting on stationary swings at the playground, and they want you to push them. Which one will be easier to get moving? If you pushed both of them with the same amount of force, which one would go faster? This illustrates Newton's 2<sup>nd</sup> Law.
  - Have a student jump from a stationary skateboard and observe the motion of the skateboard. Then have a student stand on a stationary skate board and throw a heavy object, like a medicine ball. This demonstrates Newton's Third Law.

### Reflection

Following this activity, students could write about how what they learned applies to launching objects into orbit. For example, they should understand that it is more challenging to launch a heavy object, like a space shuttle, than a light object, like a satellite. They might also write about the challenges involved in the design process after observing the unpredictable path of the cars.

### Assessment

Students should be assessed on the outcome of their self- or group-designed car. A basic understanding of the forces involved in propelling the car and the limitations of the car can be demonstrated by the students by successfully propelling the car forward a modest distance.

### Additional Resources

Below are links to several videos that we have made demonstrating these experiments. These are also included in the SOCK resource CD.

Soda Type: <http://www.youtube.com/watch?v=KfbnkiDcwUU>

Cany Type: <http://www.youtube.com/watch?v=1BFqw1r2mAA>

Nozzles Size: [http://www.youtube.com/watch?v=EZNUd\\_q1uc8](http://www.youtube.com/watch?v=EZNUd_q1uc8)

Bottle Size: <http://www.youtube.com/watch?v=ad15rTfyejM>

<http://www.youtube.com/watch?v=HNXEuFMGbD4>

<http://www.youtube.com/watch?v=0Ms417gieiM>

Advanced analysis of thrust: <http://exploration.grc.nasa.gov/education/rocket/rockth.html>

ChemMatters Article on Diet Coke and Mentos:

<http://acswebcontent.acs.org/education/chemmatters/CMatter0207.pdf>

Sample of the corresponding worksheet. See folder pocket for master copy.

# Rocket Cars

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Write down your prediction for the combination that will lead to the best car.

Soda type:

Candy type:

Number of candies:

Nozzle size:

Fuel load:

## **EXPERIMENT 1: Soda Type**

Rank the sodas in order from highest to lowest stream.

Which soda produced the highest stream?

## **EXPERIMENT 2: Candy Type**

Rank the candies in order from highest to lowest stream:

Which candy produced the highest stream?

Did you notice a difference between the types of Mentos? If yes, what was the difference?

**EXPERIMENT 3: Optimal Number**

Rank the number of Mentos in order from highest to lowest stream:

Which number of Mentos produced the highest stream?

**EXPERIMENT 4: Nozzle Size**

Rank the nozzle sizes in order from highest to lowest stream:

What size holes produced the highest stream?

**EXPERIMENT 5: Fuel Load Test**

<b>Bottle Size</b>	<b>Distance Traveled</b>
<b>0.5 L</b>	
<b>1.0 L</b>	
<b>2.0 L</b>	

Based on these experiments, which soda, candy, number of candies, nozzle size, and bottle size would make the best car?

Soda type:

Candy type:

Number of candies:

Nozzle size:

Fuel load:

## Lesson 3: Super Slingshot

This lesson challenges students to draw conclusions based on systematically collected data from a spandex slingshot activity. They will investigate how the force required to stretch spandex depends on the distance that it is stretched. In addition, they will apply what they discovered to a discussion about orbital velocity and launching objects into orbit.

### Objectives

- Students will be able to draw conclusions based on collected data.
- Students will be able to use an empirically determined model to make predictions about what is likely to happen.

### Topics

- Projectile motion
- Earth's orbital velocity

### Materials

(Items in red are included with this kit.)

- Super slingshot
- Hot Wheels radar gun
- Projectile disc (use a wheel from the dynamics cart)
- Worksheet (optional)
- Masking tape (to mark where the projectile lands)

### Advance Preparation

Estimated time: 15 minutes

1. Make sure you know how to use the spandex launcher and the radar gun.
2. Be sure you have an open space to perform the experiments!

### Conducting the Activity

Estimated time: 1.25 hours

#### 1. Introduce the topic

Introduce the spandex launcher as a prototype of a supposed "Super Slingshot" that has been developed by NASA to launch objects into space without rockets. Tell the students that it will be their job to determine if there is anything "super" about this slingshot, and if NASA's proposal is likely to work.

## 2. Explain how to use the slingshot

To cock the spandex launcher, the disc should be placed in the spandex over the patch of hot glue and pulled back until the straw points to the desired pullback distance on the attached ruler. The straw should be horizontal.

Start with a simple demonstration of how to use the slingshot - load a disc and pull the slingshot back 6cm and release it. The disc should fall quickly and travel only a short distance.



Figure 1 - Side view of cocking the slingshot.



Figure 2 - Front view of cocking the slingshot.

## 3. Have students practice using the slingshot

Have the students experiment with the spandex launcher. Have them pull the spandex back 8cm, launch the disc, and mark where the disc lands. Then have them predict where the disc will land if they pull back on the spandex 16cm and mark their prediction. Were their predictions correct?

Most students will guess that the disc will go twice as far, but it will actually go four times as far (be sure to account for this when setting up so that no one gets injured!).

Then tell the students that it's time to do more extensive testing on the material. Explain that we are interested to see how fast the slingshot can launch our "Flying Saucers" to determine if NASA will be able to launch them into space with a much larger "Super Slingshot."

## 4 . Explain how to use the Hot Wheels radar gun

If you point the radar gun at an object and hold down the trigger, the gun will continuously record the speed of the object. When the trigger is released, the maximum speed of the object is displayed. The students should keep the dial settings on "mph" and the Hot Wheels logo. Note that the speed gun measures speed in Hot Wheels mph, where the ratio of Hot Wheels mph to actual mph is 64:1.

### 5. Have students practice using the radar gun

Have a few students walk side-by-side at the same speed in the same direction, while another student uses the radar gun to measure their speed. Have all of the students try this so that they are comfortable operating the radar gun.

### 6. Prepare for the experiment

Students should be separated into groups of 4 students, and rotate through the positions described below.

- A. Two students should hold the wooden ring that has the spandex attached to it.
- B. Another student should stand in front of the slingshot with the radar gun.
- C. Another student should pull the disc and spandex back, in preparation for launch.

Students should rotate positions until all of the data is recorded.

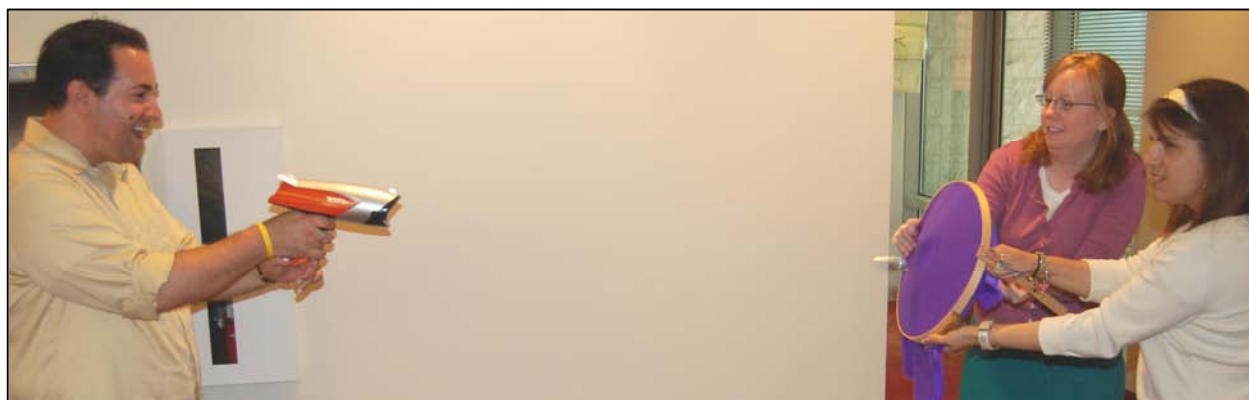


Figure 3 - Launching the disc.

### 7. Carry out the experiment

**Warning: If you are using more than one slingshot, make sure that groups are spaced well so that there is little risk of projectiles hitting people. Emphasize that there should be no intentional launching objects at other students!**

Have each group follow the procedure explained above for every case on their worksheet. They should repeat each of the cases 3 times. After each trial, students should record the data on their worksheets.

Once all of the trials are completed, have the students take the average of the speeds they recorded for each distance and record it in the "average" column. Students should complete the questions in the worksheet to determine what multiple should be used to increase the speed every time the spandex is stretched twice as much. The multiple from each group should be shared with the whole class, and a class average should be computed.

**Note: We are interested in compiling data from this experiment so that we can learn more about the behavior of spandex (there have been very few formal studies on the behavior of spandex). Please send us copies of your completed worksheets!**

SOCK Data  
Society of Physics Students  
One Physics Ellipse  
College Park, MD 20740

## 8. Group discussion

*What does it take to launch a shuttle or satellite into space?*

Explain to the students that in order for an object to orbit the earth, it must be launched fast enough from the earth that it is able to fall freely in the earth's gravitational field and not crash into the ground. NASA uses really big rockets to launch their shuttles and satellites high into the atmosphere before orienting them to fall into orbit around the earth.

If you wanted to launch an object into circular orbit around the earth, you need to shoot or throw it fast enough to overcome much of the gravity of the earth. It turns out that you need a launch velocity around 18,000 mph to get something into near-earth orbit! Anything less and the object will fall back to the ground as shown in Figure 4, A (larger visual included in folder pocket).

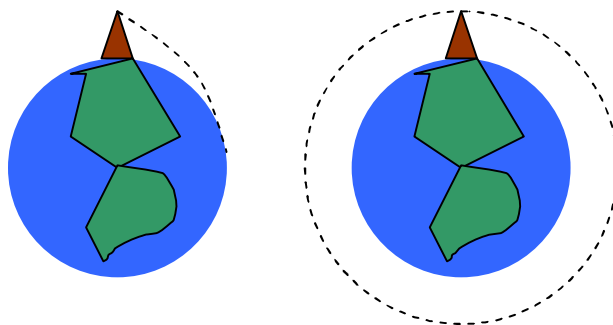


Figure 4 -      A) An object launched at a speed below 18,000 mph      B) An object launched at 18,000 mph

After talking about this with the students, explore the relationship between the distance the spandex was stretched and how fast the disc traveled (we expect a squared relationship, such that when the distance the spandex stretches is doubled, the speed of the projectile is quadrupled).

Once students understand the general relationship between the distance stretched and how fast the disc travels, ask them to help you determine how far the "Super Slingshot" must be pulled back in order to launch the disc into orbit around the earth. The distance should be about 30 feet! Is that possible?

Depending on how the data collection goes, this might be a good opportunity to discuss the importance of repeating experiments several times. It may take students a few tries to get reasonable readings from the Hot Wheels radar gun. How do you know whether a data point is valid?

### Extensions

- Purchase a large sheet of spandex from a local fabric store and use it to launch larger objects ó like a football ó in an open field. This will provide an opportunity for students to observe the trend between stretch distance and launch velocity on a larger scale.
- Have advanced groups calculate the velocity needed to launch an object into circular orbit around the earth at an altitude of 400km (Figure 4, B). See solution below.

#### Orbit Velocity

The gravitational force between the earth and an object is given by  $F_g = \frac{GMm}{r^2}$ , where  $G$  is the gravity of the earth,  $M$  is the mass of the earth,  $m$  is the mass of the object, and  $r$  is the distance between the object and the center of the earth. If you want to launch something into circular orbit around the earth at a given altitude, the gravitational force at that altitude must be equal to the centripetal force at that altitude.

Or, in mathematical terms,  $\frac{GMm}{r^2} = \frac{mv^2}{r}$ , which simplifies to  $v = \sqrt{\frac{GM}{r}}$ .

Putting in the values for  $G$ ,  $M$ , and  $r$  (radius of the earth + 400km) yields,

$$v = \sqrt{\frac{(6.7 \times 10^{-11} \text{ N} \cdot \text{m}^2 / \text{kg})(6 \times 10^{24} \text{ kg})}{(6.77 \times 10^6 \text{ m})}} = 7706 \text{ m/s, which is about 18,000 mph!}$$

Objects launched at speeds below 18,000 mph will be pulled back to the ground by the earth's gravity, as shown in Figure 4, A.

- Have advanced groups calculate the velocity needed to launch an object outside the range of the earth's gravity (for an object to escape the earth's gravity completely, its kinetic energy must be greater than the gravitational potential energy of the earth, or, in mathematical terms,  $\frac{GMm}{r} = \frac{1}{2}mv^2$ ). This is called the escape velocity.
- Have students record this data in a spreadsheet program and find the best fit line (make sure they include the (0, 0) point as one of their data points). This will give the students a means for finding an exact equation (should be a quadratic) to predict the behavior of the spandex and determine how far it would need to be stretched in order to launch a disc into orbit.

**Reflection**

Students can reflect on the feasibility of launching something into space using this technique. Is it practical? Why or why not?

Older students might also reflect on the accuracy of extrapolating data beyond the range of measurements. When is this technique acceptable?

**Assessment**

Assessment for this activity is based on the students' predictions for the stretch distance required for sending an object to space. In addition, their data can be assessed by comparing the multiple that each group calculates for the relationship between the stretched distance and the launch velocity.

**Additional Resources:**

Orbits

<http://hyperphysics.phy-astr.gsu.edu/hbase/orbv.html>

NASA site on orbits

<http://asd-www.larc.nasa.gov/SCOOOL/orbits.html>

Sample of the corresponding worksheet. See folder pocket for additional sheets.

# Super Slingshots!

Name: \_\_\_\_\_ Date: \_\_\_\_\_

In this activity we're going to be using Spandex slingshots and Hot Wheels radar guns to learn about launching things into orbit!

Fill out the first three columns with the data you collect, and then calculate the average speed of the trials and fill in the rest of the chart.

Pull Back Distance (cm)	Launch Speed Trial 1 (Hot Wheels Units)	Launch Speed Trial 2 (Hot Wheels Units)	Launch Speed Trial 3 (Hot Wheels Units)	Average (Hot Wheels Units)	Average (mph) (average in Hot Wheels Units divided by 64)
6					
8					
10					
12					
14					
16					
18					

1. Look at the data in the **lightly shaded blocks**; note that the pullback distance is doubled, from *6cm* to *12cm*.

Re-write the average mph speed for *6-cm* pullback here. \_\_\_\_\_

Now, re-write the mph speed for the *12-cm* pullback here. \_\_\_\_\_

About how many times faster is the *12-cm* pullback speed than the *6-cm* pullback speed?

A) about twice as big B) more than twice as big, or C) less than twice as big

2. Now do the same thing for the **darkly shaded blocks**:

Re-write the average mph speed for 8-cm pullback here. \_\_\_\_\_

Now, re-write the mph speed for the 16-cm pul-back here. \_\_\_\_\_

About how many times faster is the 16-cm pullback speed than the 8-cm pullback speed?

A) about twice as big B) more than twice as big, or C) less than twice as big

3. When you double the pullback distance, by about how much is the launch speed multiplied? \_\_\_\_\_.

**How far would we have to pull back the spandex to get an object into orbit?**

1. Estimate the average speed (in mph) of the disc for the pullback distances below. **Note that each pullback distance is two times the previous one**; use this fact to estimate the speeds.

<b>Pullback Distance (cm)</b>	<b>Estimated Average (mph)</b>
10	
20	
40	
80	
160	
320	
640	
1280	
2560	

2. How many cm would you have to pull back the super slingshot to get the disc into orbit? Remember that you need a speed of 18,000 mph. \_\_\_\_\_

3. How many feet is this? Multiply by .033 to convert cm to feet) \_\_\_\_\_

## Demonstrations

Based on 2006 SOCK participant surveys, we found that many SPS chapters used components of the SOCK for demonstrations during large events. Thus, we include below brief alternatives pulled from the longer lessons that can be used in such situations.

### Seatbelt Safety

The Crash Test Smarties experiment makes a good demo if you are in an environment where small groups of people rotate through. You can have all of the equipment set up, and lead people through a qualitative discussion of what happens to the various Play-Doh people after the cart hits the wall.

### Diet Coke and Mentos Fountain

*This should be done outside.* The reaction produced when Mentos candies are added to a bottle of Diet Coke is both exciting and captivating. The demonstration could easily fit into a presentation on propulsion as discussed in the lesson above, but it could also serve as a nice visual for a presentation on pressure.

To conduct the demonstration, you can either drop Mentos into an open bottle of Diet Coke and observe the thick stream that erupts from the bottle, or you can use a starter cap to create a more directional and faster moving stream.

You can expand this demonstration to include simultaneously started bottles and introduce variables like different types of sodas or candies to show how Diet Coke and Mentos stack up to the competition.

### Diet Coke and Mentos Rocket Car

*This should be done outside.* This demonstration is perfect for emphasizing Newton's Third Law as the fizzing soda leaves the bottle the cart is propelled forward. All of the pieces for this demonstration are supplied or simply strap a bottle of Diet Coke onto the provided dynamics cart and use the starter cap to hold the Mentos inside of the bottle. Start with the cart and bottle system positioned upright, release the Mentos into the solution, and then drop the cart onto its four wheels and let it roll!

To see how this is done, view the videos on the supplied CD or watch the YouTube versions at <http://www.youtube.com/watch?v=adl5rTfyejM> , <http://www.youtube.com/watch?v=HNXEuFMGbD4>, and <http://www.youtube.com/watch?v=0Ms4l7gieiM> .

### Super Slingshot Distance Comparison

Spandex obeys a stretching law similar to Hooke's Law for a spring, but the force is proportional to the cube of the stretched distance. Consequently, the velocity (and horizontal displacement) of a projectile launched from a piece of spandex will change in proportion to the square of the stretched distance.

Have a student launch a projectile using the spandex slingshot and then make a prediction about how far the projectile will travel if the slingshot is stretched twice as far. Two measurements that work particularly well with the provided contraption are 8-cm and 16-cm. Most of the time students will predict that the projectile will travel about twice as far. When the projectile travels about four times as far, they will be surprised!

### Giant Spandex Slingshot

*This should be done outside.* This demonstration is a more dramatic version of the above demonstration. Purchase a piece of spandex several yards long (two or three yards is sufficient) and have two or more people hold the ends of it so that the spandex is under some tension. Another person can load the slingshot with a large object, like a football, and fire it forward.

### Spandex Space

This demonstration focuses on planetary motion. The spandex system can be used to create a model of gravitational potential. This is not a highly accurate model for the gravitational potential because spandex obeys an inverse cube root force law and gravity follows an inverse square law relationship. However, it is close enough for demonstrating orbits and planetary motion.<sup>1</sup>

To assemble the model, place a marble in the launching area of the spandex slingshot. Twist a paperclip around the spandex above the marble, as shown below. Then suspend mass from the free end of the paperclip until the desired shape is attained. Roll marbles along the circumference of the spandex to put them into orbit.

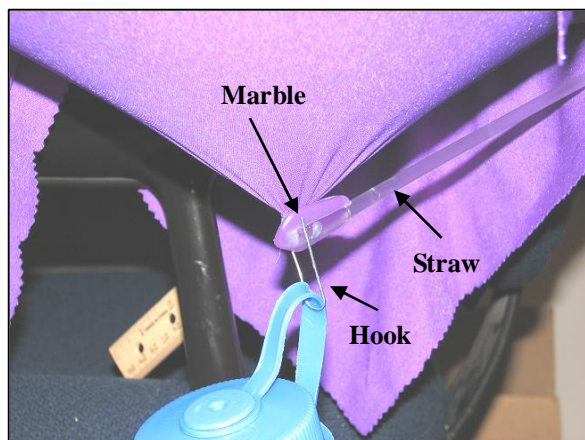


Figure 1 ó Construction of the gravitational potential model.

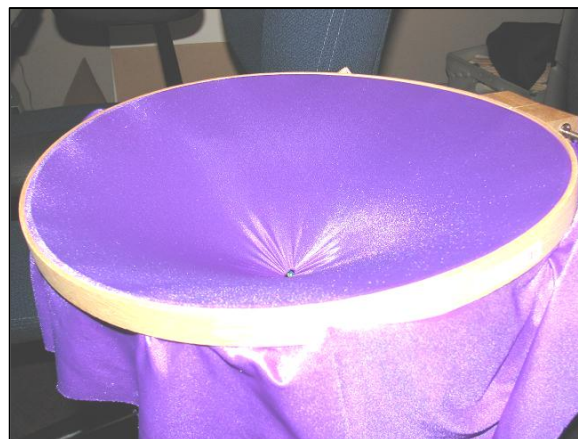


Figure 2 ó Top view of completed model.

<sup>1</sup> Gary White and Michael Walker, "The shape of the Spandex and orbits upon its surface," *American Journal of Physics*, 2002.

## Rainbow Glasses

Every year, the SOCK has included Rainbow Glasses and this year is no different! There are plenty of wonderful things that can be done using these glasses, which show the spectral components of any visible light source. The lenses in these glasses are diffraction gratings, with a line spacing of 4.5 microns in the horizontal and vertical directions.

Theory tells us that for a given wavelength, maxima will occur according to  $d \sin \theta = m\lambda$ , where  $\theta$  is the diffraction angle,  $d$  is the distance between slits,  $m$  is the order, and  $\lambda$  is the wavelength of incident light. Qualitatively, this means that the Rainbow Glasses bend longer wavelengths of light (i.e. red light) at a greater angle than shorter wavelengths. This is illustrated in Figure 3, where you can see that the red maxima are farther away from the light source than the blue. Note that this is opposite from a prism, which separates light into its component colors by dispersion. Red light passing through a prism will be bent less than blue light, as shown in Figure 4.

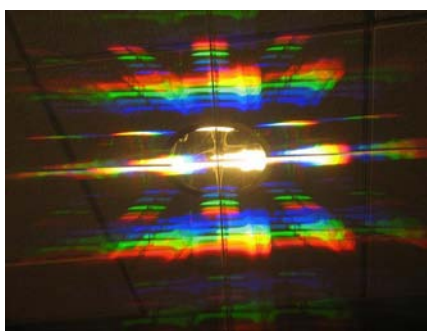


Figure 3 ó A light source as seen through Rainbow Glasses.

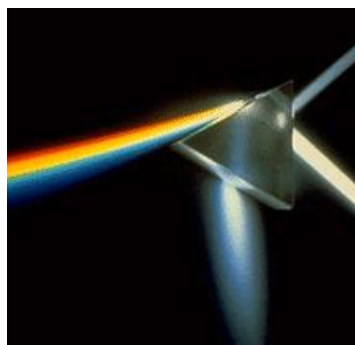


Figure 4 ó Light traveling through a prism. Image © The Exploratorium, [www.exploratorium.edu](http://www.exploratorium.edu).

As a demonstration, you could have people put on the glasses and look at different light sources such as neon or mercury, LEDs, lasers, and fluorescent bulbs. Have them think about how the rainbows are different than one another. What does this mean? How could knowing the spectrum of an unknown light source help you identify the source?

## Doppler Shift

The radar guns used in the first two experiments capitalize on other wavelengths in the electromagnetic spectrum ó radio waves. The guns emit a radio beam, which bounces off of the object and is reflected back to a detector on the gun.

The frequency of the emitted and reflected beams are different because of the Doppler effect ó the change in frequency of a wave as seen by someone moving relative to where the waves are coming from. Knowing the emitted frequency and measuring the reflected frequency allows us (or the radar gun) to determine the velocity of the object.

The radar gun emits at about 10.5 GHz. At this frequency, a relative velocity of 1 mph will cause a shift of around 16 Hz. The direction (either toward or away from the gun) determines whether the frequency appears to increase or decrease. The visible part of the spectrum behaves in the same way ó when you move relative to an emitting source, the light is Doppler shifted.

By examining the spectrum produced by diffraction glasses, you can visualize what this shift looks like. If you are moving toward a yellow light source, the light will appear bluer. Conversely, if you are moving away from the source, the light will appear redder. These shifts are used in astronomy to study the relative motion of stars and the expansion of the universe.

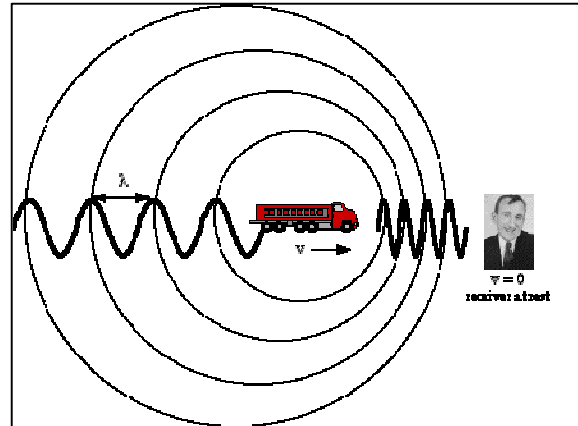


Figure 5 ó A stationary observer (in this case Johann Doppler), will hear a siren at a higher frequency when the fire truck is coming toward him than when the fire truck is going away from him. *Image courtesy NASA.*

## Construction Details

### I. Starter Cap Construction

#### Materials

- Soft drink cap
- 1.25ø finishing nail
- 2 Mentos Mint candies
- 1.75ø binder clip
- Drill with assorted drill bits

#### Directions

- Take a soft drink cap and drill a ¼ø hole through the top of cap. Label the cap with the hole size (i).
- Drill a small hole through the center of the two Mentos Mint candies so that the shaft of the nail can go through the candy (ii)
- Insert the finishing nail through two Mentos Mint candies.
- Place the tip of the nail through bottle cap and secure it with a binder clip.

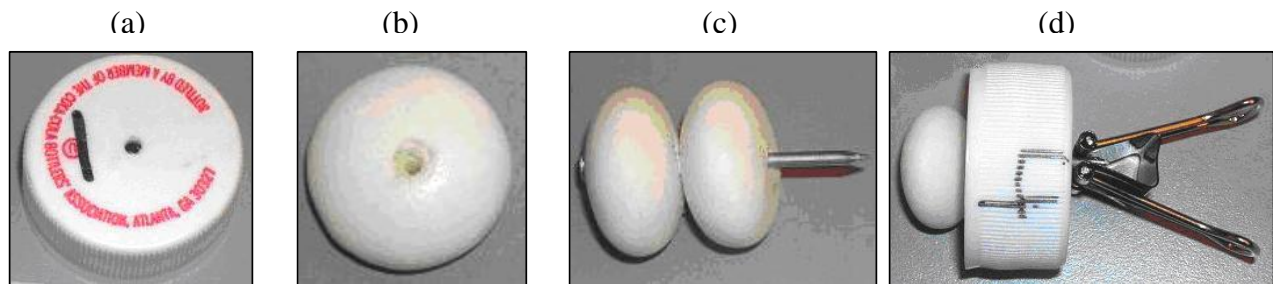


Figure 1 ó Components of a starter cap.

### II. Multiple Starter System

#### Materials

- One 1.25ø X 0.5ø X 8ø wooden board
- 5 pieces of 24ø string
- Five 1.125ø wood screws
- 5 starter caps
- Hot glue gun

#### Directions

- Drill 5 wood screws half way into the board at even intervals.
- Tie a piece of string to each screw and use hot glue to ensure a secure knot.
- Tie the binder clips from the starter caps to the other end of the string and secure them with hot glue. See Figure 2.



Figure 2 - Multiple starter system.

**Note:** You can have as many starters on this system as you want - just adjust the number of wood screws, string, and starter caps. Our pictures show a 10 cap system, however, we found that it is easier to compare the streams from five bottles at a time.

### III. Seat Attachment Construction

#### Materials

- One 1ö X 2ö X 3ø wooden board
- Six 1.25ö wood screws
- Wood glue
- Drill and various drill bits (or drill press)
- Radial chop saw or similar cutting device
- Two 1.5ö bolts with fitting nuts, washers, and lock washers
- 1 package non-stretching shoe laces
- 3 flat thumbtacks
- 1 package heavy duty Velcro strips

#### Directions

- Using a radial chop saw, cut 3 chair backs (A), 3 seats (B), and 1 base (C). Refer to Figure 3 for part identification and dimensions.
- Mark the seat back locations on the base (given in Figure 4).
- Mark a spot ¼ö from the end of the base and drill a hole the size of your bolt all the way through the board. This will be used to secure your seat attachment to the dynamics cart.
- Pre-drill holes for 1 ¼ö wood screws going from the bottom of the base partly into the chair backs. There should be two screws per seat back, as shown in Figure 4.

**Note: Graphics are not to scale. Use measurements given in diagrams.**

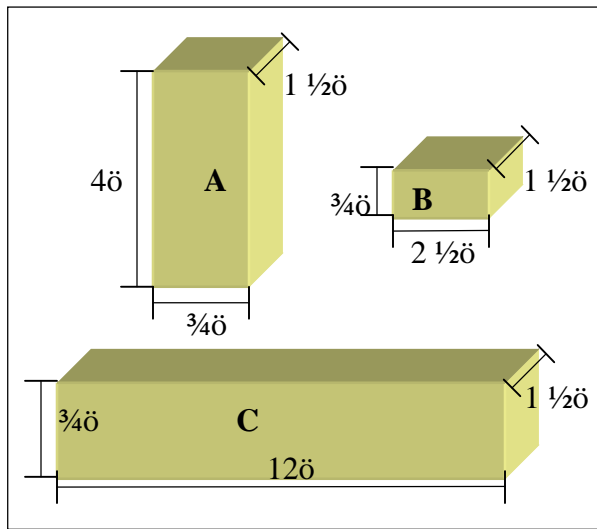


Figure 3 ó Part labels and their respective dimensions.

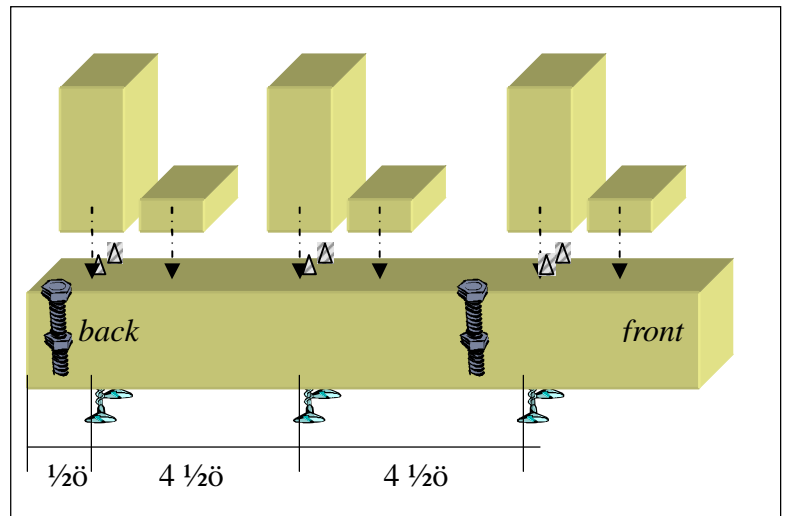


Figure 4 ó Distances for chair backs and locations of bolts and wood screws for Part C.

- e. Screw in the seat backs.
- f. Use wood glue to attach the seats to their respective places.
- g. Position the dynamics cart attachment onto the cart and secure the back end with your bolt assembly. Tighten securely.
- h. Drill another hole the same size as in step c between the middle seat and the front seat. Go through the attachment and the dynamics cart. Secure with same bolt assembly as in step g.
- i. Cut three pieces of string approximately 6ö long. Use Velcro strips to secure one end of each seatbelt and use a thumb tack for other end. Arrange into the following configurations: shoulder and waist belt (back), waist belt (center), and no seatbelt (front).

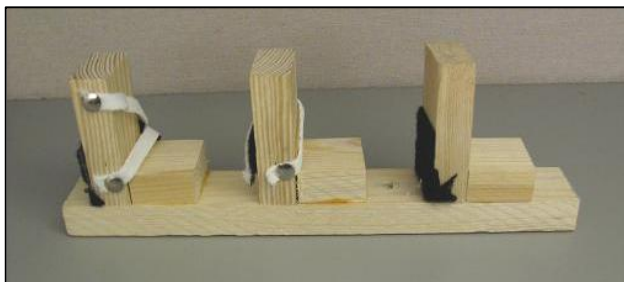


Figure 5 ó Side view of completed seat attachment.

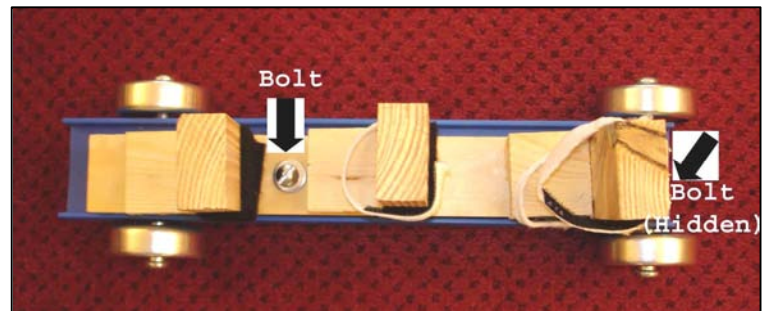


Figure 6 ó Top view of seat attachment with bolt placements.

## IV. Super Slingshot Construction

### Materials

- a. One 14" craft hoop.
- b. One 2"X 2" square of spandex material
- c. Metric ruler
- d. Drinking straw
- e. 1/8" bolt, nut, and lock washer assembly
- f. Drill
- g. Hot glue gun

### Directions

- a. Drill a hole through the side of craft loop that is the width of your bolt, or slightly larger.
- b. Drill a matching hole through the end of the ruler so that the 1" mark lines up with the edge of the hoop when the ruler is upright and bolted in place (see Figure 8).
- c. Put the spandex material in the craft hoop and pull on it to remove most of the slack. Tighten the adjustment screw.
- d. Use hot glue to attach a straw to the center of the underside of the slingshot. The straw should lay parallel to the spandex and point toward the ruler, see Figure 7.
- e. Attach ruler with nut and bolt assembly and tighten so that the ruler is perpendicular to the hoop, as shown in Figure 8.

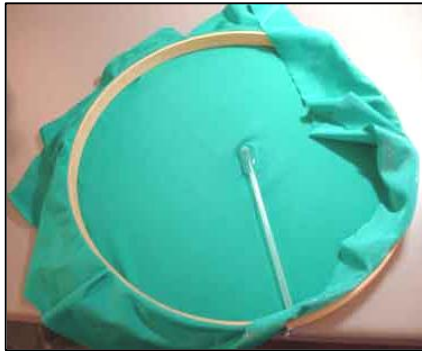


Figure 7 ó Picture of super slingshot with straw attachment.



Figure 8 ó Completed super slingshot.

## Vendor List

Item	Source & Additional Info	Estimated Price
Dynamics Cart	<i>The Science Source</i> <a href="http://www.thesciencesource.com/">http://www.thesciencesource.com/</a> Economy Cart #32280	\$15.60
Seat Attachment (Requires building ó see page 36)	<i>Local hardware store</i>	Varies
Propping Block	<i>Local hardware store</i>	Varies
Play-Doh	<i>Retail stores such as Target and Wal-Mart and toy stores</i>	\$25 / pack of 24
Cookie Cutter	<i>Ebay</i> <a href="http://hub.ebay.com/buy">http://hub.ebay.com/buy</a> Key word: ðCookie Cuttersö	Varies
Hot Wheels Radar Gun	<i>Target Stores Online</i> <a href="http://www.target.com">http://www.target.com</a> Product ID # 4661205	\$24.99
AAA Batteries	<i>Various</i>	\$6.00 / pack of 8
Mentos Candies	<i>Various</i>	\$1.25 / pack
Small Binder Clips	<i>Office supply store</i>	\$1.50 / pack of 12
Finishing Nails	<i>Local hardware store</i>	\$2.50 / box
14ö Wooden Sewing Hoop	<i>Local craft store</i>	\$5.00
1 yd <sup>2</sup> Spandex	<i>Local fabric store</i>	\$12.00
Metric Ruler	<i>Office supply store</i>	\$2.00
Drinking Straw	<i>Local grocery store</i>	About \$2.00 / pack of 100
Rainbow Glasses	<i>SPS National</i> <a href="http://www.spsnational.org/about/merchandise.htm">http://www.spsnational.org/about/merchandise.htm</a>	\$30.00 / pack of 20

## Notes