



NASA Out-of-School Learning Network

# Rockets Rock

module





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# NASA Out-of-School Learning Network

The NASA Out-of-School Learning (NOSL) Network is designed to offer inquiry-based science, technology, engineering, and mathematics (STEM) learning experiences that connect students with NASA scientists, engineers, and mission content related activities. The NASA engineering design challenge: *Parachuting Onto Mars* has been paired with the Rockets Rock Module and is located on the NOSL Web site. This engineering design challenge allows students the opportunity to work through the engineering design process used by NASA scientists.

The complete module is designed to provide the student with an understanding of

- Newton’s Third Law of Motion
- The engineering design process
- Forces and interactions

## Scope and Sequence

The Rockets Rock module covers the following Next Generation Science Standards (NGSS) for middle school students:

### **Next Generation Science Standards**

#### *Middle School Physical Science (MS–PS)*

- MS-PS2-2. Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.

#### *Middle School Engineering Design (MS–ET)*

- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.



### **Disciplinary Core Ideas**

- Forces and motion
- Types of interactions
- Developing possible solutions

### **Science and Engineering Practices**

- Asking questions and defining problems
- Planning and carrying out investigations
- Constructing explanations and designing solutions

### **Crosscutting Concepts**

- Cause and effect
- Systems and system models
- Stability and change

### **Connections to the Nature of Science**

- Scientific knowledge is based on empirical evidence

### **Connections to Engineering, Technology, and the Applications of Science**

- Influence of science, engineering, and technology on society and the natural world

# BACKGROUND INFORMATION FOR FACILITATORS

## Newton's Three Laws of Motion

The activities in this module will demonstrate principles from Sir Isaac Newton's three laws of motion that are related to rocketry. The following background information is for instructors who conduct these activities. Understanding how to successfully launch a rocket depends on understanding the laws of motion that Newton developed based on earlier research by Galileo.

### First Law of Motion

Objects at rest remain at rest and objects in motion remain in motion in a straight line unless acted upon by an unbalanced force.

### Second Law of Motion

Force equals mass times acceleration ( $f = ma$ )

### Third Law of Motion

For every action there is an equal and opposite reaction.

Before looking at each of these laws in detail, a few terms should be explained:

**Rest and Motion** used in the first law can be confusing. Both terms mean rest or motion in relation to the object's surroundings.

When sitting in a chair a person is at *rest*. It doesn't matter if the chair is in the cabin of a jet plane while on a cross-country flight or if the plane is on the ground. Passengers (the objects) are still considered to be at *rest* because the airplane cabin is moving with them. If they get up from their seats on the airplane and walk down the aisle, they are in relative *motion* because they are changing their positions inside the cabin.

**Force** used in the second law is a push or a pull exerted on an object. *Force* can be exerted in many ways such as muscle power, movement of air, and electromagnetism. *Force* is usually exerted on rocket by burning propellants that expand explosively.

**Unbalanced force** refers to motions that are in opposition to each other. The forces on a soccer ball at rest on the playing field are balanced. Give the ball a good kick, and the forces become unbalanced (Fig. 1). Air drag (a force) gradually slows the ball and gravity causes it to bounce on the field. When the ball stops bouncing and rolling, the forces are in balance again. Take the soccer ball into deep space, far away from any star or other significant gravitational field and give it a kick. The kick exerted on the ball is an *unbalanced force*. Once the ball is no longer in contact with the foot, the forces on the ball become balanced again, and the ball will travel in a straight line forever. The forces are balanced when the soccer ball is at rest or when the ball is moving at a constant speed and in a straight line in space. The forces are unbalanced when the ball is accelerating or changing its direction.

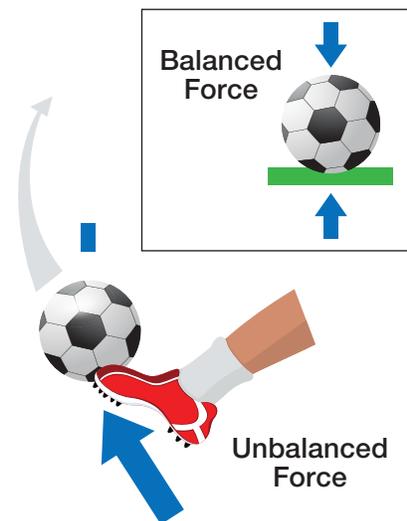


Figure 1. Balanced and unbalanced forces.

**Mass** refers only to the amount of matter contained in an object. *Mass* and *weight* are often confused. They are not the same thing. *Weight* is a force and is the product of mass times the acceleration of gravity.

The *mass* remains the same whether the object is on Earth, in Earth orbit, or on the Moon unless it is changed in some way.

**Acceleration** relates to motion and describes a change in motion. Usually, change refers to increasing speed, like what occurs when you step on the accelerator pedal of a car. *Acceleration* can also be changing direction.

This is what happens on a carousel. Even though the carousel is turning at a constant rate, the continual change in direction of the horses and riders (circular motion) is an *acceleration*. The carousel platform exerts unbalanced forces on the riders and prevents them from going in straight lines. The platform continually accelerates the riders in a counterclockwise direction as shown in Figure 2.

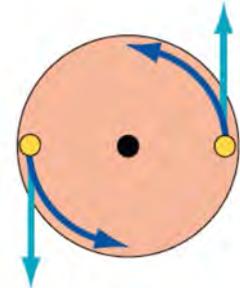


Figure 2. Top view of two riders on a carousel.

**Action** used in the third law is the result of a force. When a cannon fires and the cannon ball flies through the air, the movement of the cannon ball is considered an *action*. Air being released from an inflated balloon is also considered an *action*.

**Reaction** is related to action. When a cannon fires, the cannon ball flies through the air, but the cannon itself recoils backward and reacts. When the air rushes out of the balloon, the balloon shoots the other way, another *reaction*.

## Newton's First Law of Motion

Newton's first law of motion points out that an object at rest, such as a rocket on a launch pad, needs the exertion of an unbalanced force to cause it to lift off.

The amount of the thrust (*force*) produced by the rocket engines has to be greater than the force of gravity holding it down. As long as the thrust of the engines continues, the rocket accelerates. When the rocket runs out of propellant, the forces become unbalanced again. Gravity takes over and causes the rocket to fall back to Earth. After it lands the rocket is at rest again and the forces are in balance.

One very interesting part of the first law has enormous implications for spaceflight. When a rocket reaches space, atmospheric drag (*friction*) is greatly reduced or eliminated. Drag is an unbalancing force within the Earth's atmosphere yet is virtually absent in space.

A rocket traveling away from Earth at a speed greater than 11.186 kilometers per second (6.95 miles per second) or 40,270 kilometers per hour (25,023 mph) will eventually escape Earth's gravity. The rocket will slow down, but Earth's gravity will never slow it down enough to cause it to fall back to Earth. Ultimately, the rocket will travel to the stars. Because no additional rocket *thrust* will be needed, the rocket's inertia will cause it to continue to travel outward. Four spacecraft are actually doing that as you read this. Pioneers 10 and 11 and Voyagers 1 and 2 are on journeys to the stars!

## Newton's Third Law of Motion

It is useful to jump to the third law and come back to the second law later. The third law is the principle of action and reaction. In the case of rocket engines, the *action* is the force produced by the expulsion of gas, smoke, and flames from the nozzle end (Fig. 3). The *reaction* force propels the rocket in the opposite direction.

When a rocket lifts off, the combustion products from the burning propellants accelerate rapidly out of the engine while the rocket slowly accelerates skyward. The action and reaction are equal, but the mass of the gas, smoke, and flames being propelled by the engine is much less than the mass of the rocket being propelled in the opposite direction. Even though the force is equal on both the rocket and propellants, the effects are different. Newton's first law, the law of inertia, explains why. Because it takes a force to change the motion of an object, the greater the mass, the greater the force required to move it.



Figure 3. Action and reaction.

## Newton's Second Law of Motion

The second law of motion relates force, acceleration, and mass.

The law is often written as the equation  $\mathbf{f} = \mathbf{ma}$

The *force* or *thrust* produced by a rocket engine is directly proportional to the *mass* of the gas and particles produced by burning rocket propellant times the *acceleration* of those combustion products out the back of the engine. This law applies only to what is actually coming out of the engine at the moment and not the mass of the rocket propellant that will be consumed later. The implication of this law for rocketry is that the more propellant ( $m$ ) consumed at the moment and the greater the acceleration ( $a$ ) of the combustion products out of the nozzle later, the greater the thrust ( $f$ ).

## Conclusion

In conclusion, Newton's laws of motion explain just about everything you need to know to become a rocket scientist. However, knowing the laws is not enough. You have to know how to apply them, such as: How can you create enough thrust to exceed the weight of the rocket? What structural materials and propellant combinations should you use?

# Move It!

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# MOVE IT!

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Grades: 6 to 8   Prep Time: 0.25 hour   Activity Time: 0.5 hour

## About This Activity

This activity, which was taken from the NASA Adventures In Rocket Science Guide, illustrates how rockets and airplanes move forward.

## Background

Engines (propulsion systems) provide a constant source of thrust to move vehicles forward and to overcome drag. In this activity, balloons will move in the opposite direction of the flow of the released air (propulsion system) because every action has an opposite and equal reaction (Newton's third law). Since the air will be released from one small hole, the release of the air will be in one direction.

## Procedure

### Step 1

Ask students why an airplane is able to move forward.

### Step 2

Tell students they are going to conduct a simple experiment to see how a jet or plane moves forward.

### Step 3

Distribute *Balloon Thrust Experiment Log* and balloons. Let students know they should follow the procedures on the handout and remind them to use all of their senses.

## Materials

- Balloons
- Balloon Thrust Experiment Log

## Next Generation Science Standards

MS-PS2-1. Apply Newton's Third Law of Motion to design a solution to a problem involving the motion of two colliding objects.

## Learning Objective

Learners will

- Conduct an experiment with a system that moves due to equal and opposite actions and reactions

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

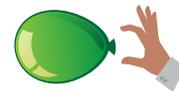
### Balloon Thrust Experiment Log

1. Fill the balloon with air.
2. Hold it so that no air gets out, but do not tie a knot.
3. Hold the balloon up with the opening facing to your left.
4. Let go of balloon. Write down your observation below.



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5. Repeat steps 1 to 4 with the opening of the balloon facing to your right.  
Write your observation below.



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6. Repeat steps 1 to 4 with the opening of the balloon facing up.  
Write your observation below.



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7. Repeat steps 1 to 4 with the opening of the balloon facing the ground.  
Write your observation below.



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8. In general, describe what happens when you release the balloon.  
Write your observation below.

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9. What did you learn?

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10. How did this activity relate to rockets and their motion?

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# Launch a Rocket

## From a Spinning Planet

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# LAUNCH A ROCKET FROM A SPINNING PLANET

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Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1 hour

## About This Activity

This activity, which was taken from NASA Space Place, illustrates how difficult it is for a rocket that is launched from the Earth (which is spinning on its axis) to meet the intended target.

## Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

## Learning Objective

Learners will

- Understand that rockets are launched into space with precise timing in order to meet their intended destinations

## Materials

- Several small balls (for example, tennis balls, softballs, whiffle balls, golf balls, or bean bags)
- Two containers
- Merry-go-round or any device that will allow you to turn around in a circle

# LAUNCH A ROCKET FROM A SPINNING PLANET

## Background

Gravity is at work on Earth and in space. Because all objects are in constant motion orbiting around something or moving toward or away from something, how do engineers aim a spacecraft in order to meet its intended target? Not only do Earth and the target constantly move in different orbits around the Sun, the Earth is spinning at about 1,670 kilometers per hour (1,037 miles per hour).

In determining when to launch, NASA engineers and scientists have to consider things like where the object they are aiming for will be when the rocket arrives. Because of the gravity and motion of other objects, engineers and scientists are able to use these effects to provide extra thrust to a rocket, which will save a lot of fuel and time in getting to a distant destination. Figures 1, 2, and 3 show examples of these principles.

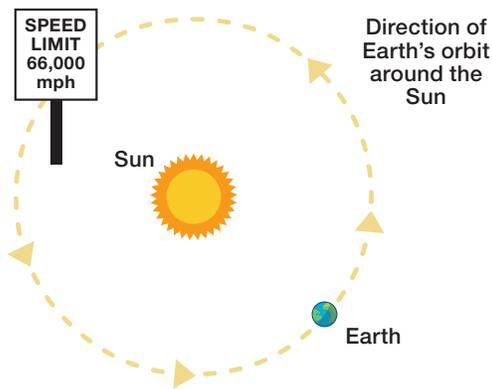


Figure 1. Earth goes around the Sun at a brisk 107,000 kilometers per hour (66,000 miles per hour). If our interplanetary spacecraft is aimed in the same direction Earth is already going, it will get a big head start.

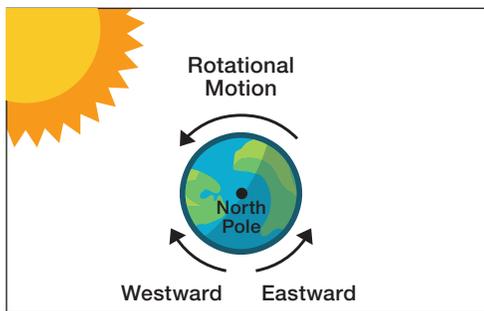


Figure 2. Also, Earth rotates eastward on its axis, one complete turn each day. At the equator, Earth's surface is rotating at 1,675 kilometers per hour (1,041 miles per hour). So if we launch the rocket toward the east, it will get another big boost from Earth's rotational motion.

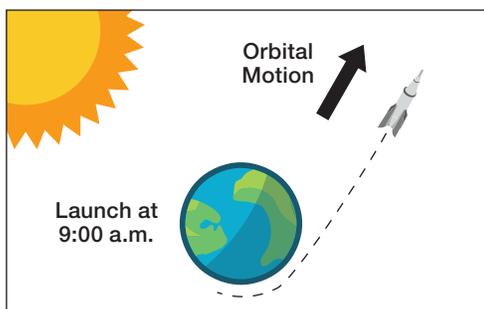


Figure 3. Now, we launch eastward. We pick the time of launch to give the rocket time to accelerate as it goes partway around Earth. Then, when the spacecraft is headed in the same direction as Earth's orbital motion around the Sun, the rocket gives it a final boost out of Earth orbit and on its way.

## **Procedure**

### **Step 1**

Gather up small balls such as tennis balls, softballs, whiffle balls, golf balls or bean bags.

### **Step 2**

Put the balls in a container or bag to make them easy to carry. Use the second container as the target each student will throw the balls into.

### **Step 3**

Take materials to the nearest park or playground that has a merry-go-round. Note, not the kind with horses, but the kind that is pushed around and hopped on to ride (Fig. 4). If there is no access to a merry-go-round, any equipment that can turn in a complete circle can be used.

### **Step 4**

Place the container on the ground about 3 or 4 meters (9 to 12 feet) from the merry-go-round. Then have each student step up on the merry-go-round with the container of balls.

### **Step 5**

Without moving the merry-go-round, have each student toss a few balls into the target on the ground.

### **Step 6**

Leaving the container of balls on the merry-go-round, have student hop off, push it to get it going slowly, and have the student hop back on.

### **Step 7**

Have each student try to toss the balls into the target on the ground as the merry-go-round spins.

### **Step 8**

Ask students how adding the turning motion affected hitting the target. Explain that timing is everything in picking a time to launch. Space engineers and scientists have to consider quite a number of things. Most of them have to do with getting the biggest boost possible from the launch pad on Earth and determining how to have their spacecraft meet up with the target.

## LAUNCH A ROCKET FROM A SPINNING PLANET

### Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

#### *Support:*

For students who are unable to participate on the merry-go-round, use a spinner from any board game. Spin the spinner and have students roll a coin across the path of the spinner. The spinner will deflect the coin towards another path. Have students repeat for a trial of three times and record the path.

#### *Complexity:*

Have students redo the activity and change the variables in the activity. For example use lighter or heavier balls to determine if this makes a difference, increase the distance of the target from the merry-go-round, etc.

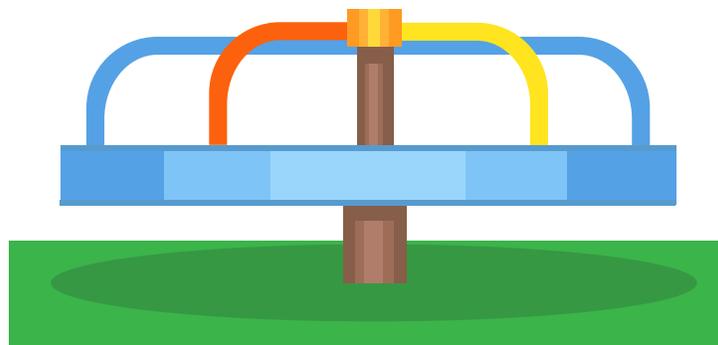


Figure 4



LAUNCH A ROCKET FROM A SPINNING PLANET  
Student Handout

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

1. While standing on the merry-go-round without moving, make a prediction as to how difficult it will be to toss balls into the target container provided while the merry-go-round isn't moving.

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2. While standing on the merry-go-round without moving, toss a ball into the target your instructor has provided three times. How difficult was it for you to make the target?

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3. Were you able to make it all three times?

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4. Predict how difficult it will be to toss balls into the target container provided while the merry-go-round is moving.

---

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5. Push the merry-go-round to get it going slowly, and then hop back on. As you spin around, toss the balls three times into the target container. How difficult was it to make the target container?

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6. Were you able to make it all three times?

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7. What did you have to change in order to hit the target?

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8. What surprised you about this activity?

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# Rocket Races

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# ROCKET RACES

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1 hour

## About This Activity

In this activity, which was taken from the NASA Rockets Educator Guide, students will construct racing cars from Styrofoam food trays and power them with the thrust of an inflated balloon. Students will measure the distance the racers travel in three trials. Between trials, students will redesign their racers to improve performance and solve any mechanical problems that crop up. At the end of the activity, students will submit a detailed report on their racer designs and how they performed.

## Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

## Learning Objective

Learners will

- Investigate Newton's third law by designing, testing and developing solutions to construct a rocket racer that meets the design requirements

## Materials

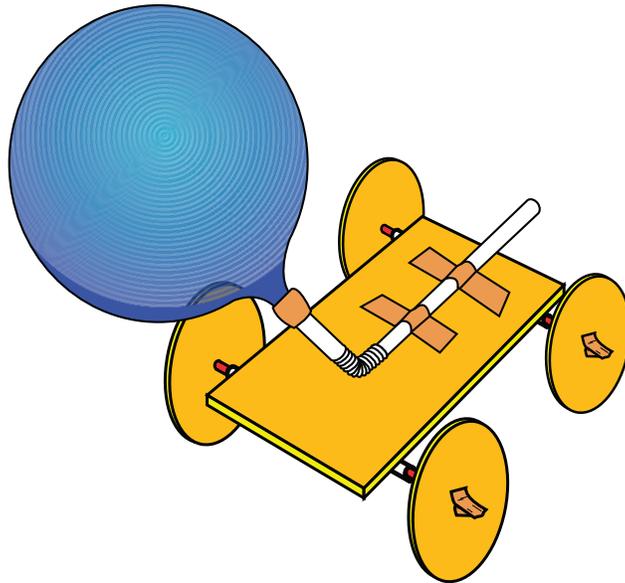
- Styrofoam food trays
- Small plastic stirrer straws, 2 per racer
- Sharp pencil
- Scissors (optional)
- Flexi-straws, 3 per racer
- Ruler meter stick or metric measuring tape for laying out race course
- Masking tape
- Sandpaper (optional)
- One round balloon (4- or 5-inch when blown up)
- Student handouts

## Background

The rocket racer is an excellent demonstration of Newton's third law. Air is compressed inside a balloon that is expanded. When the nozzle (outlet) is released, the balloon returns to its original uninflated size by propelling the air out the nozzle. The straw mounted to the balloon extends the nozzle beyond the rear end of the car. The action force of the expelling air produces a reaction force that pushes the racer in the opposite direction. The racer's wheels reduce friction with the floor and the racer should take off down the racecourse.

Although the rocket racer seems simple, there are many challenging complexities in its operation. In principle, Newton's second law, the less mass the car has, the greater its acceleration will be. Generally, heavy rocket racers do not do as well as lighter racers. Smaller racers, however, are limited by other factors. Racers with short wheelbases tend to circle or partially lift off the floor. Balance becomes a problem. The mass of the balloon may cause the car to tilt nose down to the floor, causing a poor start.

The engineering design of the racer is very important. Many designs are possible, including wide, narrow, and I-beam-shaped bodies and three, four, or even six wheels. Students will have to review the tradeoffs of their designs. For example, an extra-long body may provide a straighter path, but the car might travel a shorter distance as a result.



## Procedure

### Step 1

Explain the activity to the students. Demonstrate the action-reaction principle by inserting a pin through the straw and into a pencil eraser (Fig. 1). Inflate the balloon and observe it pinwheel around the pencil as air rushes out. Compare this to the straight thrust produced by the balloon in the rocket cars.

### Step 2

Give students the *How to Build a Rocket Racer* handout (Fig. 2). Review the construction steps and demonstrate how to snap out parts, mount the wheels, and attach the straw to the balloon.

### Step 3

Stress that the racer shown in the instructions is basic. Encourage students to think of various original designs because many designs are possible. Have them draw their design on the *Rocket Racer Design Sheet*.

### Step 4

Give students the *Rocket Racer Data Sheet*. Explain what data to collect and how to fill out the graphs. They will shade in the distance traveled by the racer in each trial. Explain that they will make improvements between each trial and record the data.

### Step 5

Distribute materials to students and measure the racer course.

### Step 6

When students are ready to race, have one or two at a time inflate their balloons and pinch off the end of the straws to keep the air inside. Have them place their racers just behind the starting line and release the straws. Have students measure the distance along the straight line that the racer traveled, regardless of how much their racers curved.

### Step 7

Post distance records to motivate students and encourage them to modify their racers to set new records.

### Step 8

Stress to the students that they must

- Draw their design on the *Rocket Racer Design Sheet*, that many designs are possible and that the one shown is just a basic design
- Run trial 1, then make improvements to their design, run trial 2, then make improvements to their design, run trial 3
- Record their data on the *Rocket Racer Data Sheet* after each trial

## Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

*Support:*

Cut out the pieces for a basic car design so that students can assemble and test.

*Complexity:*

Have students use a variety of materials like balsa wood or corrugated cardboard to construct the racer.

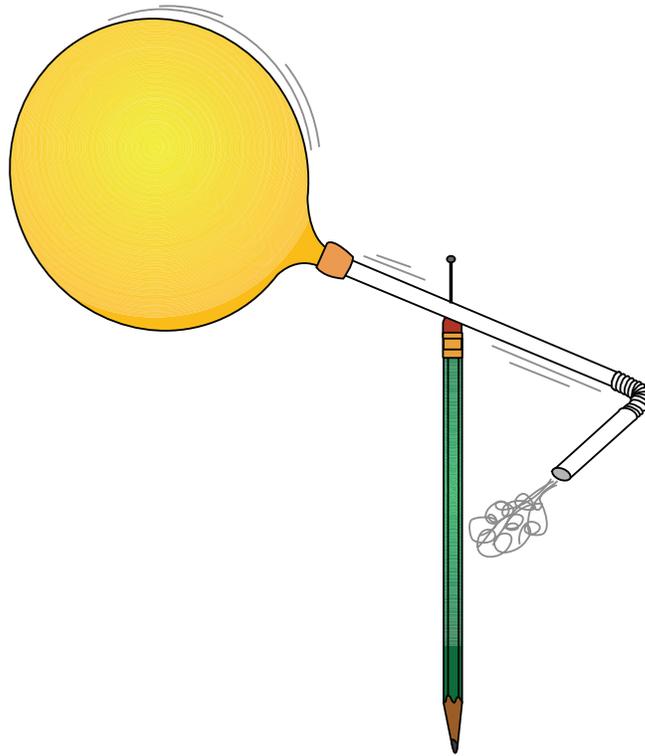
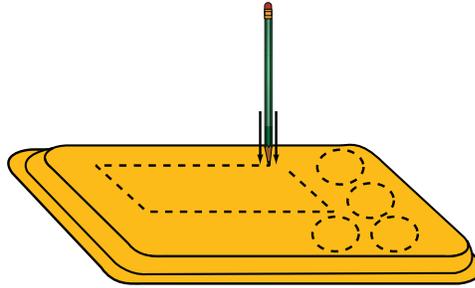


Figure 1

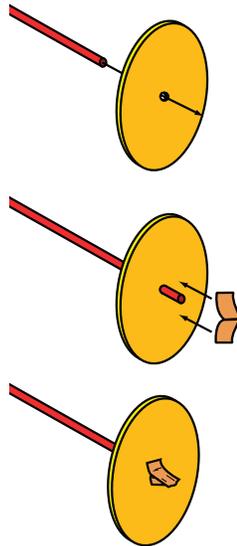


## How to Build a Rocket Racer

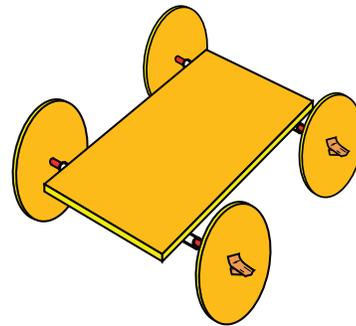
1. Lay out your pattern on the Styrofoam tray. You will need a racer body and wheels. Use a pencil point to score the Styrofoam. Snap out your pieces and smooth them. Make sure your wheels are round! Use sandpaper to round the wheels OR press them on a hard surface and roll them.



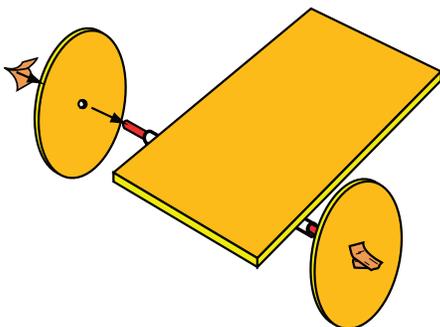
2. Punch a small hole in the center of each wheel with the pencil. Push the axle (stirrer straw) through the hole of one wheel so that it extends 1 cm on the other side. Pinch a piece of masking tape around the end of the straw and smooth it on to the wheel. Do the same for the second axle. Do not add wheels to the other ends yet!



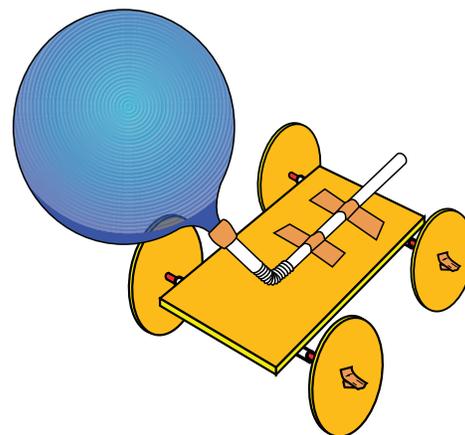
4. Slide the second wheel and axle through the remaining straw and mount the remaining wheel at its opposite end.



3. Cut two large straws to the size you want. Tape them parallel to each other on the bottom of the racer body at opposite ends. Slide a wheel and axle through one of the straws and mount a second wheel on the other end of the axle.



5. Blow up the balloon and then let the air out. Next, slip the straw into the balloon as shown. Use masking tape to seal the balloon nozzle to the straw. Squeeze the tape tightly to seal all holes. Test the seal by blowing up the balloon again through the straw.



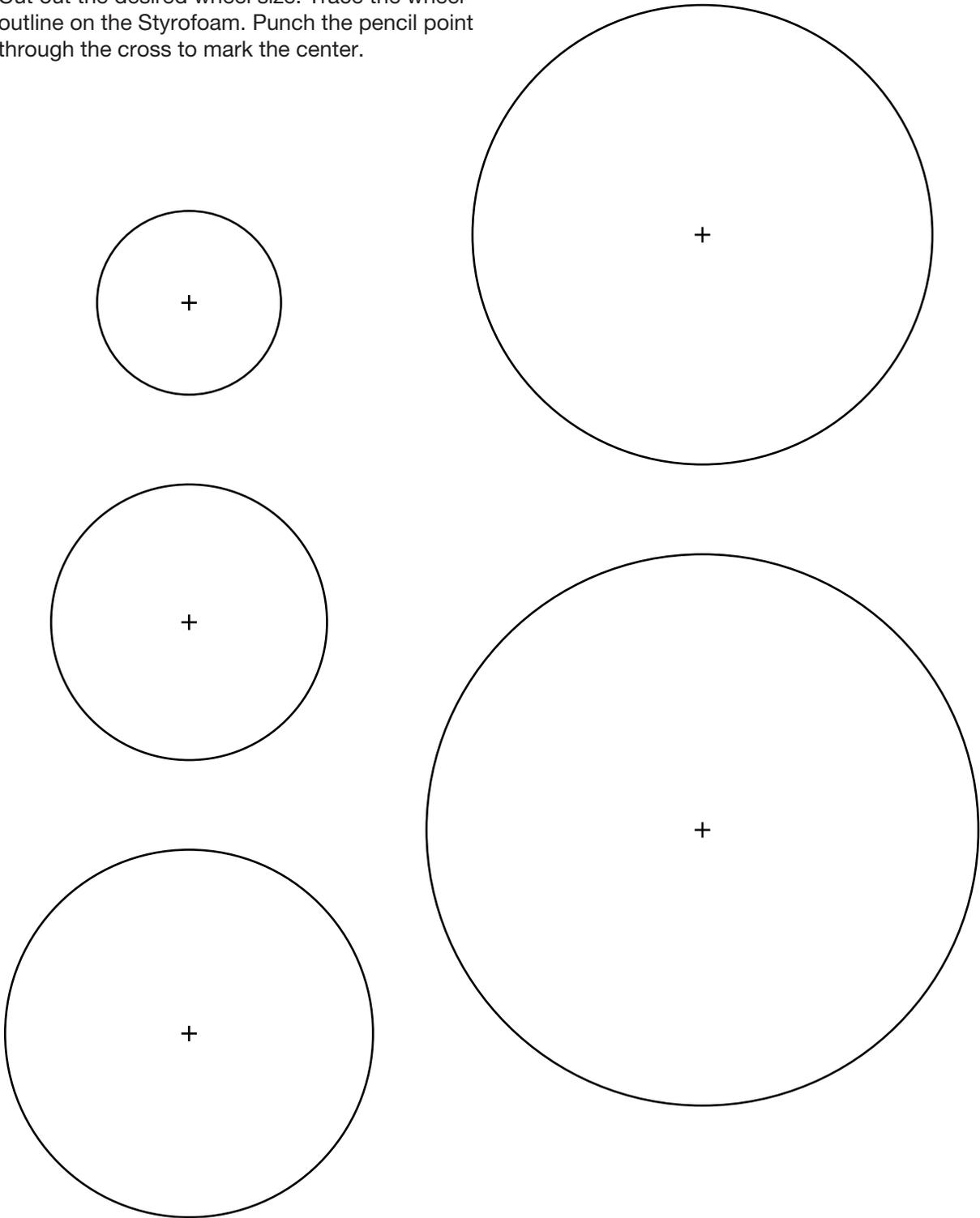
6. Mount the balloon and straw to the racer with masking tape as shown. Be sure the end of the straw (rocket nozzle) extends off the end of the racer body.

Figure 2



## Wheel Patterns

Cut out the desired wheel size. Trace the wheel outline on the Styrofoam. Punch the pencil point through the cross to mark the center.

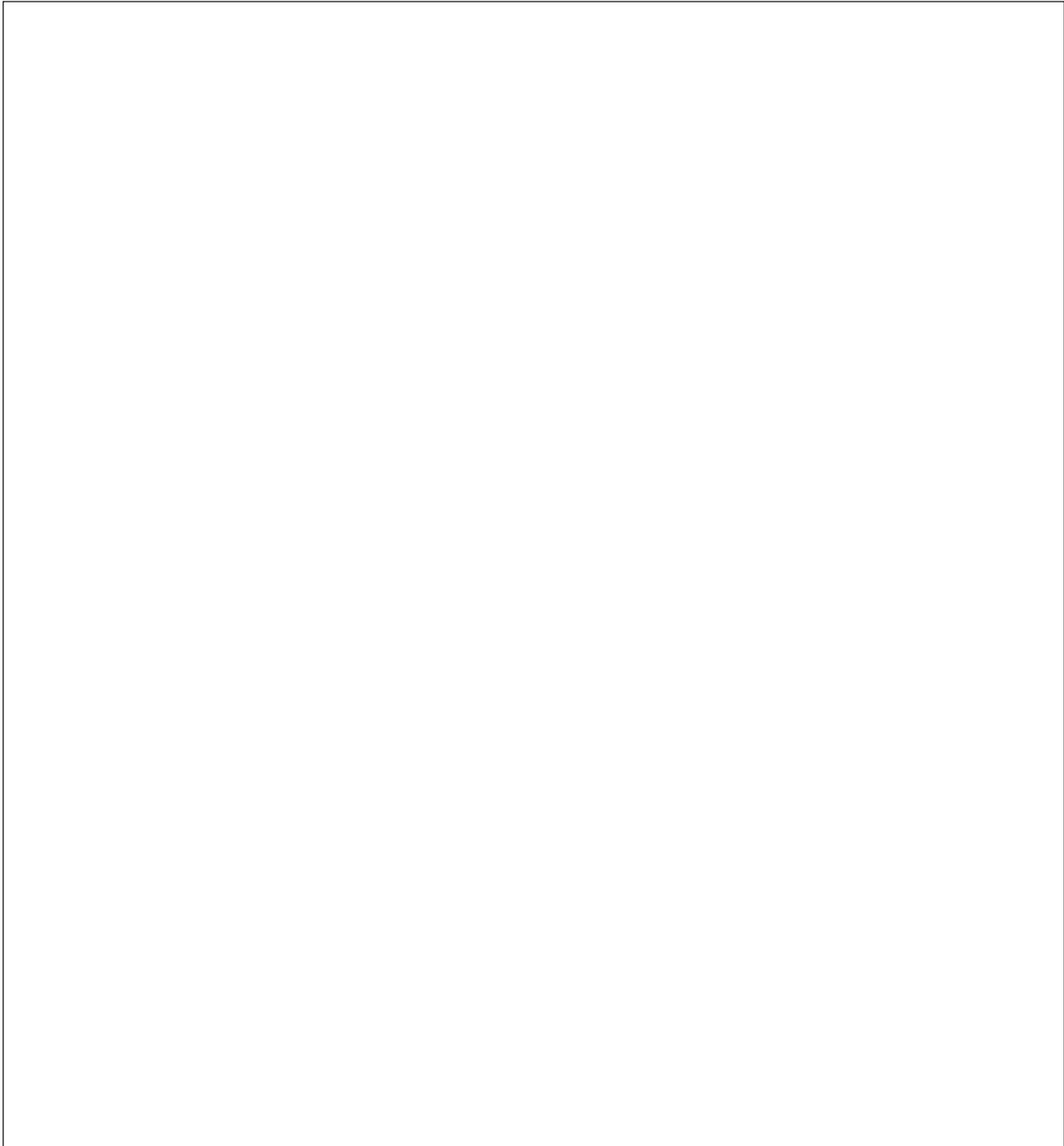




Name: \_\_\_\_\_

### **Rocket Racer Design Sheet**

Draw a diagram showing your best design for a rocket racer.

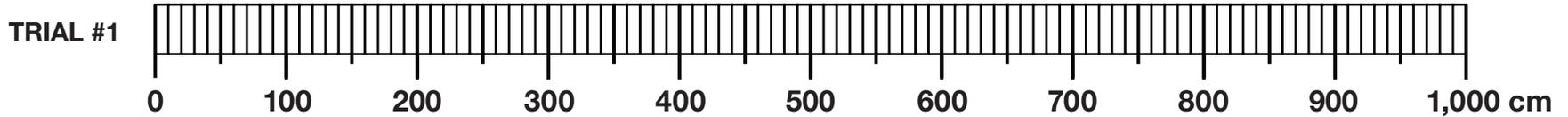
A large, empty rectangular box with a thin black border, intended for a student to draw their best design for a rocket racer. The box occupies most of the page's width and height.



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

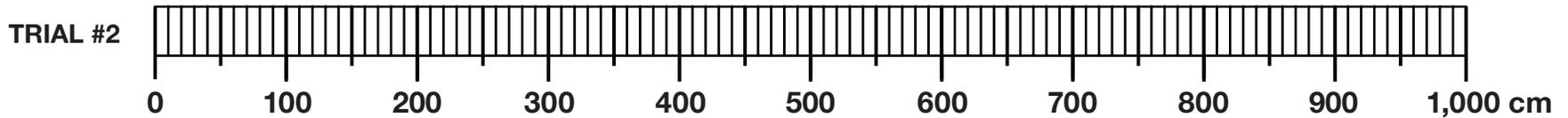
## Rocket Racer Data Sheet

Shade in the graph showing how far your rocket racer traveled in centimeters.



Describe how your rocket racer ran (straight, curved, circles, stuck, etc.). \_\_\_\_\_

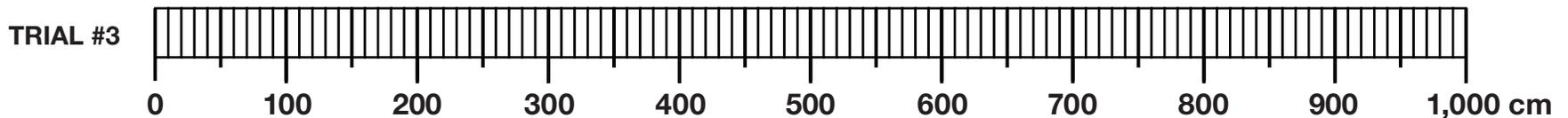
Did your racer perform as well as you hoped? Explain why or why not. \_\_\_\_\_



How did you improve your rocket racer? \_\_\_\_\_ Predict how far your racer will run. \_\_\_\_\_ cm

Describe how your rocket racer ran. \_\_\_\_\_

Did your improvements work? Why or why not? \_\_\_\_\_



How did you improve your rocket racer? \_\_\_\_\_ Predict how far your racer will run. \_\_\_\_\_ cm

Describe how your rocket racer ran. \_\_\_\_\_

Did your improvements work? Why or why not? \_\_\_\_\_



# Balloon Staging

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# BALLOON STAGING

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1 hour

## About This Activity

This activity, which was taken from the NASA Glenn Research Center Space Flight Systems Web site, simulates a multistage rocket launch.

## Background

Traveling into outer space takes enormous amounts of energy. Much of that energy is used to lift the rocket and propellants. To eliminate technological problems and the cost of building giant one-piece rockets to reach outer space, NASA, as well as all other space agencies, uses a rocket technique that was invented by a 16th-century fireworks maker named Johann Schmidlap. To reach higher altitudes with his aerial displays, Schmidlap attached smaller rockets to the top of larger ones. When the larger rockets were exhausted, the smaller rocket climbed to even higher altitudes. Schmidlap called his invention a *step rocket*.

NASA improved on Schmidlap's invention by *multistaging* rockets. Larger first stage rockets carry the smaller upper stages for the first few minutes of flight. When the first stage is exhausted, it is released to return to the Earth. In doing so, the upper stages become much more efficient and can reach much higher altitudes because they do not have to carry the expired engines and empty propellant tanks that make up the first stage. Space rockets are often designed with three or four stages that each fire in turn to send payloads into orbit.

## Materials

- 2 different colored long balloons (round balloon will not work)
- Nylon monofilament fishing line (enough to cross the classroom)
- 2 plastic straws (milkshake size and unbendable)
- Styrofoam cup
- Masking tape
- Scissors
- Student handout

## Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

## Learning Objective

Learners will

- Demonstrate how several stages of a rocket operate in controlled release to propel a rocket to a farther distance

## Procedure

### Step 1

Prepare the launch site by threading fishing line through two straws. Stretch the fishing line straight across a room and secure the ends by taping or tying. Make sure the line is just high enough for people to pass safely underneath.

### Step 2

Discuss the background information with students. Place students in groups of two and distribute the materials.

### Step 3

Cut the cup in half around the circumference to form a continuous 2-inch ring (Fig. 1).

### Step 4

Inflate the first balloon (balloon A) about 3/4 full of air and squeeze its opening (nozzle) tight. Pull the nozzle through the Styrofoam ring and continue to pinch it. Have your group member inflate the second balloon (balloon B). The front end of balloon B should extend through the ring a short distance. As balloon B inflates it will press against the nozzle of balloon A and take over the job of holding it shut. It may take a few attempts to get it to work correctly.

### Step 5

Take your balloon assembly to one end of the fishing line and tape each balloon to the straw. The balloons should be parallel to the fishing line.

### Step 6

If you wish, do a rocket countdown and release balloon B. The escaping gas will propel both balloons along the fishing line. When balloon B runs out of air, it will release balloon A to continue the trip.

## Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

### *Support:*

Assist students with the staging assembly.

### *Complexity:*

Have students design and build staging balloons with three or four additional balloons to carry a set payload from one of the fishing lines to the other.

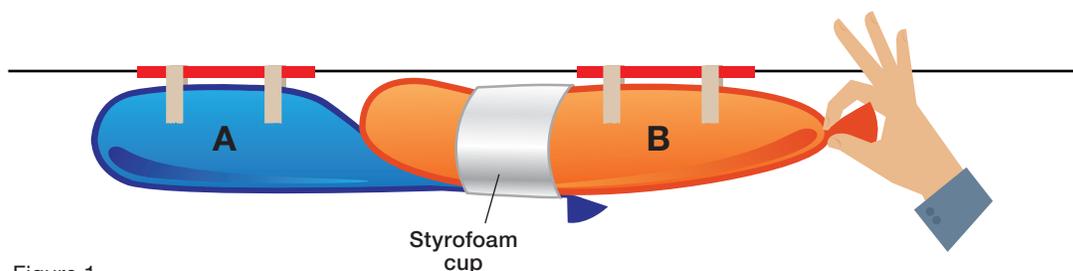


Figure 1



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

## Directions

### Step 1

Cut a Styrofoam cup around the circumference making sure that the open end is at least 2 inches wide.

### Step 2

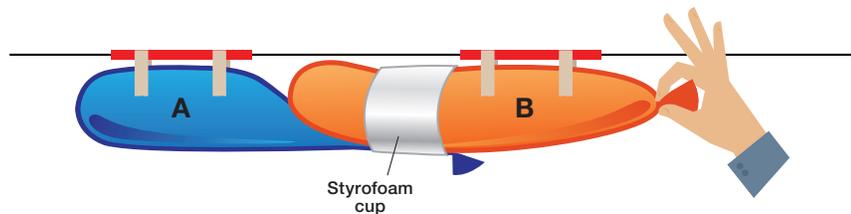
Loosen the balloons by inflating or stretching them. Inflate the first balloon about 3/4 full of air and squeeze the nozzle tight. Pull the nozzle through the ring. While your partner assists you, inflate the second balloon. The front end of the second balloon should extend through the ring a short distance. As the second balloon inflates, it will press against the nozzle of the first balloon and take over the job of holding it shut. It may take a bit of practice to achieve this.

### Step 3

Take the balloons to one end of the fishing line your instructor has set up for you to use and tape each balloon to a straw. The balloons should be pointed along the length of the fishing line.

### Step 4

Count down and release the second balloon you inflated. The escaping gas will propel both balloons along the fishing line. When the first balloon released runs out of air, it will release the other balloon to continue the trip. After you have launched, answer the questions below in complete sentences.



## Questions

1. Which one of Newton's laws does this demonstrate? Explain what the law means.

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2. What force is involved when the air is released from balloon B?

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3. Describe what happened when balloon B ran out of air and how that impacted balloon A.

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# Foam Rocket

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# FOAM ROCKET

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1.5 hours

## About This Activity

In this activity, which was taken from the NASA Rockets Educator Guide, students will construct rockets made from pipe insulating foam and use them to investigate the relationship between launch angle (trajectory) and distance.

## Next Generation Science Standards

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

## Learning Objective

Learners will

- Gain an understanding of rocket stability and trajectory by constructing and using rubber-band-powered foam rockets

## Materials

- Rubber band (size 64)
- Scissors
- Quadrant plans printed on cardstock
- Washer or nut
- Rocket construction instructions
- Launch record sheet
- 1 Tape measure
- Styrofoam food tray, cardboard, or stiff poster board
- 30 cm-long piece of 1/2-inch polyethylene foam pipe insulation
- Duct tape
- Meter stick
- Push tack
- Safety goggles
- Experiment data sheet
- Masking tape
- Student handouts

## Background

The launch of a foam rocket is a good demonstration of Newton's third law. The contraction of the rubber band produces an action force that propels the rocket forward while exerting an opposite and equal force on the launcher.

When the rocket is released, the rubber band will quickly return to its original length and launch the foam rocket in the process. On real rockets, thrust typically continues for several seconds or minutes, causing continuous acceleration, until propellants are exhausted whereas the foam rocket gets a quick pull and then coasts. Also real rockets consume propellants and their total mass diminishes whereas the mass of foam rockets do not change in flight. Nevertheless, the flight of foam rockets is similar to that of real rockets because their motion and course are affected by gravity and by drag or friction with the atmosphere.

Like feathers on an arrow, fins keep the rocket pointed in the desired direction. If launched straight up, the foam rocket will climb until its momentum is overcome by gravity and air drag. At the very top of the flight the rocket momentarily becomes unstable and flops over as the fins catch air. The rocket becomes stable again when it falls back to the ground.

When the foam rocket is launched at an angle of less than  $90^\circ$ , its path (arc) is determined by the launch angle. For high launch angles, the arc is steep, and for low angles, the arc is wider.

When a real rocket is launched straight up (neglecting air currents) the rocket will fall straight back to its launch site. If the rocket is launched at an angle of less than  $90^\circ$ , it will land at some distance from the launch site. The distance from the launch site depends on gravity, launch angle, initial velocity, and atmospheric drag.

Gravity causes the rocket to decelerate as it climbs upward and then causes it to accelerate as it falls back to the ground. The launch angle works with gravity to shape the flight path. Initial velocity and drag affect the flight time.

In the investigation, students will compare the launch angle to the range, or horizontal distance the foam rocket lands from the launch site. Gravity can be ignored because the acceleration of gravity will remain the same for all flight tests. Atmospheric drag can also be ignored because the same rocket will be flown repeatedly. Although students will not know the initial velocity, they will control for it by stretching the rubber band the same amount for each flight.

Assuming students carefully control launch angles and stretching the rubber band, they will observe that  $45^\circ$  angle launches will produce their farthest flights. They will also observe that launches of  $30^\circ$  will produce the same range as launches of  $60^\circ$ , and  $20^\circ$  will produce the same result as  $70^\circ$ , etc. Note: Ranges, (horizontal distances) will not be exact because of slight differences in launching even when teams are very careful to be consistent. However, launches can be averaged to more closely agree with Figure 1.

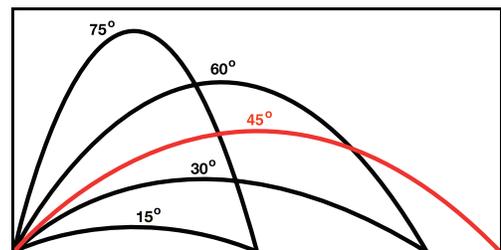


Figure 1. Launch angle vs. range for rockets with the same initial launch velocity.

## Procedure

### Step 1

Select a room with a high ceiling for the launch range, such as a cafeteria or gymnasium. Place markers on the floor at 1 meter intervals starting at 5 meters and going to 20 meters. If it is a calm day, the investigation can be conducted outside. Although the rockets can be launched outside on windy days, the wind becomes an uncontrolled variable that may invalidate the results.

### Step 2

Make a few sample rocket fins to show how they are constructed (Figs. 2 to 4). Refer to the construction page for details. Before beginning the investigation, review the concept of control. For this investigation, how much the rubber band is stretched when launching the rockets will be the control. The experimental variable will be the angle of launch. Students will compare the launch angle with the distance the rocket travels.

### Step 3

Organize students into teams of three. One student will be the launcher, the second will confirm the launch angle and gives the launch command, and the third will measure the launch distance, record it, and return the rocket to the launch site for the next flight. Have students repeat the experiment two more times and switch student roles. Teams will try different angles and determine what the best launch angle should be to obtain the greatest distance from the launch site. Teams will also calculate the average distances flown on the *Rocket Range Experiment* student handout.

### Step 4

#### Constructing a Foam Rocket

Pass out materials and *How to Build a Foam Rocket* handout.

- a. Cut one 30 cm length of pipe foam for each team.
- b. Cut four 12-cm-long slits at one end of the tube and space them equally for the fins to be mounted.
- c. Cut a 12-cm-long piece of duct tape down the middle to make two pieces. Place one piece over the other, sticky to shiny side, to make the tape twice as strong.
- d. Slip a rubber band over the tape and press the tape around the nose end of the rocket (opposite the end with the slits). Press the tape tightly and reinforce it with by wrapping another piece of tape around the tube.
- e. Cut fin pairs from the foam food tray or stiff cardboard. Notch both fin pairs so that they can slide together. Different fin shapes can be used, but they should still slide or nest together.
- f. Slide the nested fins into the slits. To finish the rocket, close off the slits with a piece of duct tape wrapped around the foam tube.

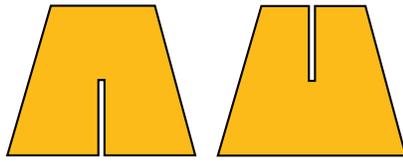


Figure 2. Cut slots the same width as the thickness of the fin stock.

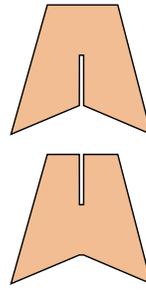


Figure 3. Different fin shapes can be used.

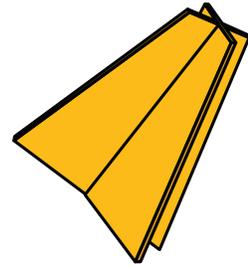


Figure 4. Nest fins together.

## Step 5

### Making and Using the Launcher (Fig. 5)

- Print the quadrant pattern on cardstock paper.
- Cut out the pattern and fold it on the dashed line.
- Tape the quadrant to the meter stick so that the black dot lies directly over the 60-cm mark.
- Press a push tack into the black dot.
- Tie a string to the push tack and hang a small weight, such as a nut or a washer, on the string. The weight should swing freely.
- Loop the rubber band over the launcher end. Pull on the fin end of the rocket until the nose cone lines up with the 30-cm mark.
- Tilt the launcher up at the angle indicated with the string and weight on the quadrant.
- The rocket is ready to launch.

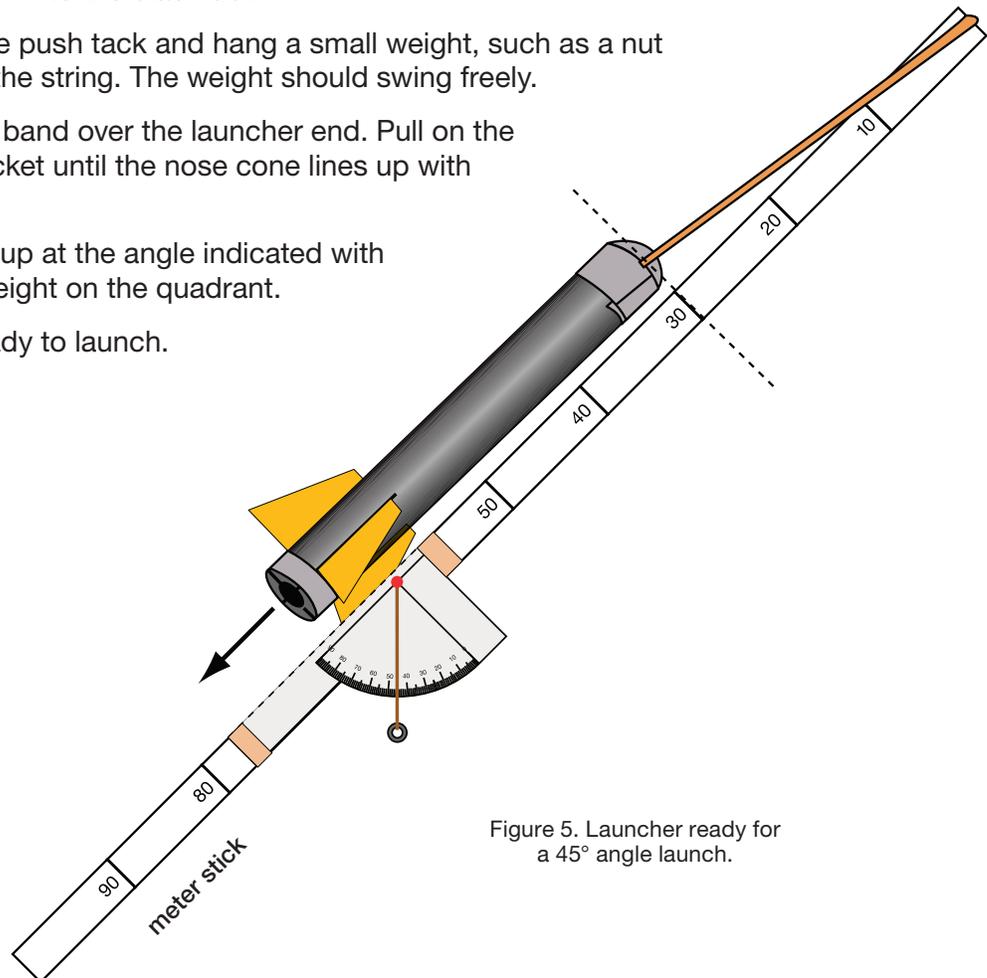


Figure 5. Launcher ready for a 45° angle launch.

## Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

### *Support:*

Assemble the foam rocket in advance and have students construct their own fin designs.

### *Complexity:*

For advanced students, use the equation below to estimate range assuming the ground is level and there is no air resistance. Students will have to determine the initial velocity. If available, an electronic photo gate (science lab probeware) with timer can be used for determining the initial velocity. Otherwise, challenge students to devise a method for estimating initial velocity. One approach might be to launch the rocket from a tabletop and measure the horizontal distance the rocket travels before it falls to the floor. Using a stopwatch, measure the time the rocket takes to reach the floor. If the rocket takes 0.25 seconds and traveled 3 meters horizontally, multiply 3 meters by 4 to get an initial velocity of 12 meters per second. Students should repeat the launch several times to improve their accuracy and average the data. This method assumes the rocket does not slow down in flight because of air drag.

$$\text{Range} = \frac{V_0^2}{g} \sin 2A$$

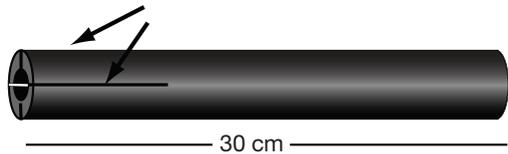
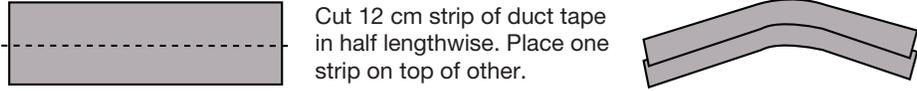
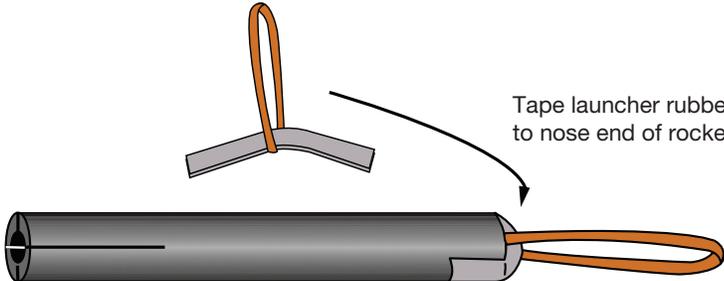
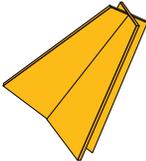
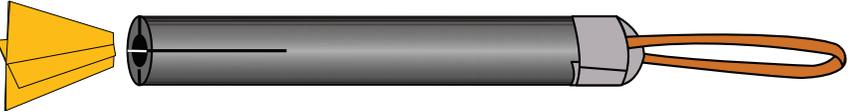
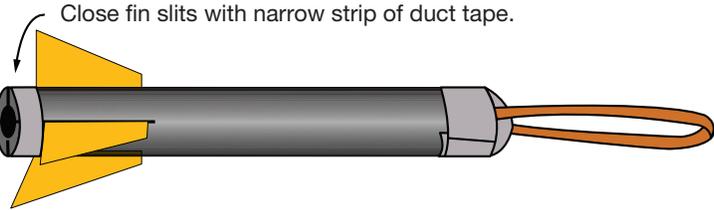
$V_0$  = initial velocity

$g$  = 9.8 meters/second<sup>2</sup>

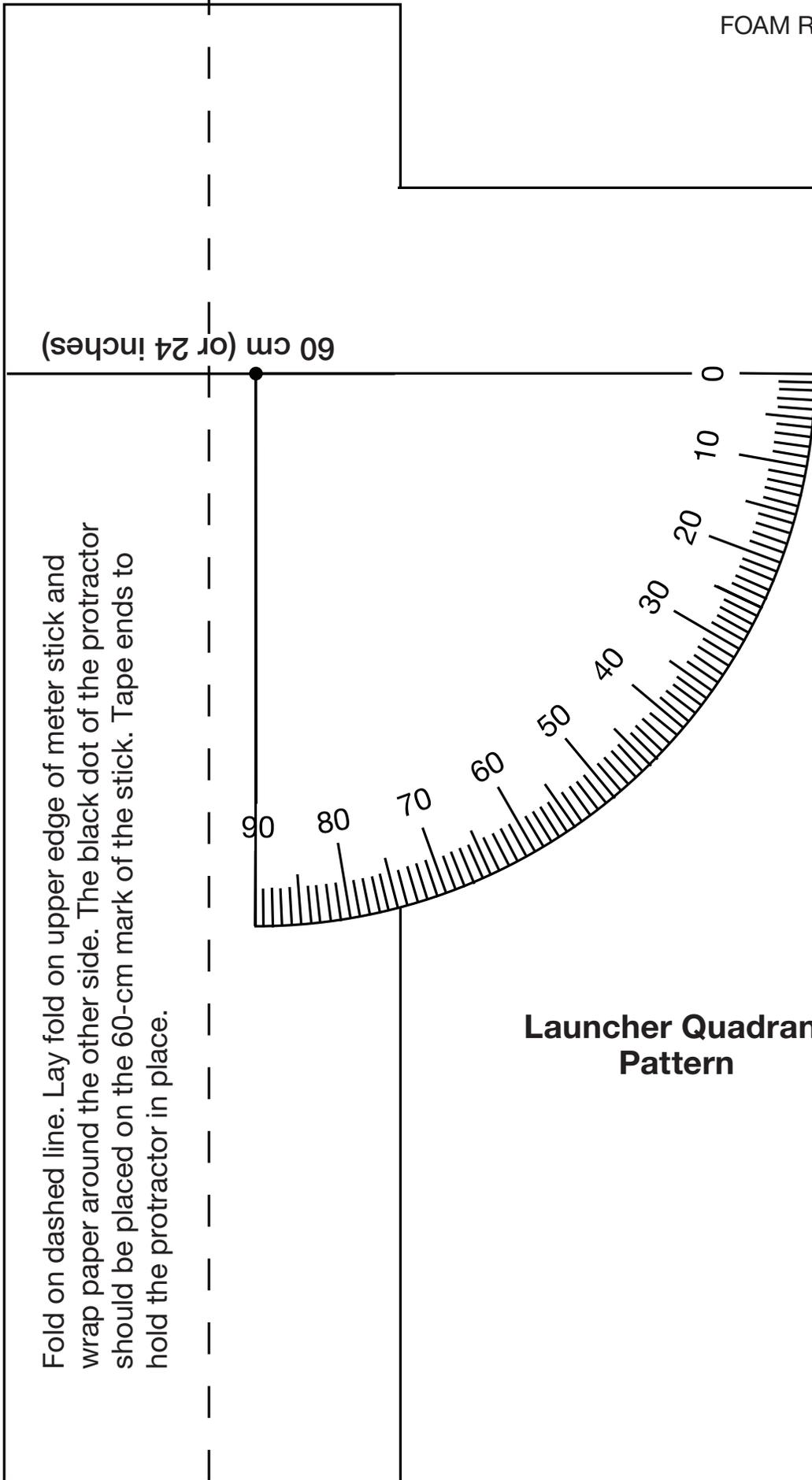
$A$  = launch angle

( $g$  is the acceleration of gravity on Earth)

## How to Build a Foam Rocket

- Cut four slits 12 cm long 90 degrees apart.
- 1**  30 cm
- 2**  Cut 12 cm strip of duct tape in half lengthwise. Place one strip on top of other.
- 3**  Tape launcher rubber band to nose end of rocket.
- 4**  Add tape strip around the nose to strengthen the attachment.
- 5**  Cut out fins with notches.
- 6**  Slide fins together.
- 7**  Slide fins into slits.
- 8**  Close fin slits with narrow strip of duct tape.
- Ready for flight!





Fold on dashed line. Lay fold on upper edge of meter stick and wrap paper around the other side. The black dot of the protractor should be placed on the 60-cm mark of the stick. Tape ends to hold the protractor in place.

60 cm (or 24 inches)

**Launcher Quadrant Pattern**



Names: \_\_\_\_\_

### Rocket Range Experiment

1. In groups of three, assign the Launch Director, Launcher, and Range Officer positions to members of your team. Team members will switch jobs later.
  - Launch Director will check to make sure the launch angle is correct and will give the launch command
  - Launcher pulls the string and launches the rocket
  - Range Officer makes sure the range is clear to launch, records the data in the tables, and retrieves the launched rocket
2. Attach the rocket to the launcher and pull back on the string until its tail reaches the 60-cm mark. Tilt the launcher until it points up at the angle needed. Release the rocket when the Launch Director gives the command.
3. Have the Range Officer measure the distance the rocket traveled and pick up the launched rocket.
4. Repeat the procedures four more times using the different angles listed in the table below.
5. Switch duties and repeat the five-launch experiment two more times using the same launch angles as in the first set of launches.
6. Average the data for the three trials across each angle and answer the questions on the back of this handout.

Launch Angle	Trial 1 Distance	Trial 2 Distance	Trial 3 Distance	Average Distance
15°				
30°				
45°				
60°				
75°				

## Questions

1. What launch angle achieved the greatest distance from the launch site?

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2. Why didn't the instructions ask you to test at  $0^\circ$  and  $90^\circ$ ?

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3. Did you notice anything interesting about the distances achieved at the various angles?

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# The Nose Cone Experts

Grades 6 to 8

INQUIRY-BASED ACTIVITY

# THE NOSE CONE EXPERTS

Grades: 6 to 8    Prep Time: 0.5 hour    Activity Time: 1 hour

## About This Activity

This activity, which was taken from the NASA Adventures in Rocket Science educator guide, is designed to give students an understanding of how design elements are important to the overall function of a device.

## Background

Aerodynamics is the branch of science that deals with the motion of air and the forces on bodies moving through the air. The four forces that act on a rocket are lift, drag, weight, and thrust (Fig. 1).

Drag is a force that opposes the upward movement of the rocket and is generated by every part of the rocket. Drag is a sort of aerodynamic friction between the surface of the rocket and the air. Factors that affect drag include the rocket size and shape, the velocity, the inclination of flow, the mass, and viscosity and compressibility of the air.

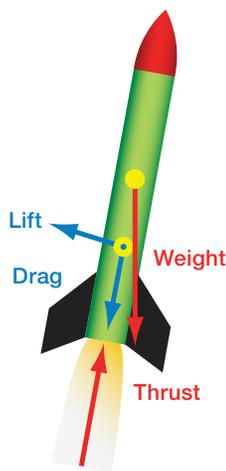


Figure 1. Forces on a rocket.

## Materials

- Nose Cone Data Table
- Books to make a path
- Tape
- Paper towel tube
- Nose cone patterns worksheet
- Yard stick or meter stick
- Leaf blower or vacuum (set to blow not vacuum)
- Long hall or open area
- Modeling clay
- Several 2-liter plastic soft drink bottles
- Cardstock
- Student handouts

## Next Generation Science Standards

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

## Learning Objective

Learners will

- Experiment with different nose cone shapes to determine the advantages and disadvantages of each type. Conic, parabolic, and flat nose cones will be tested to determine which is most aerodynamic.

## Procedure

### Step 1

Form students into groups of two members and have them build on their past experiences with aerodynamics by completing the *Nose Cone Expert Group Questions and Procedures* handout.

### Step 2

Students will construct nose cones by cutting out three different shapes on cardstock. The first two patterns are shown in Figures 3 and 4. The third nose cone should be made from a piece of paper that is glued or taped to the paper towel tube. They will then attach the nose cones onto paper towel tubes. Modeling clay can be used inside the nose cone to provide mass.

### Step 3

Use a leaf blower or a vacuum cleaner with the airflow reversed to blow the rocket backwards. This should be done on a narrow track to keep the rocket in line with the wind (books may be lined up to make this track).

### Step 4

Students should measure the distance the rocket traveled backwards, record their results, and complete the *Nose Cone Data Table* handout.

## Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

### *Support:*

Precut and assemble nose cones.

### *Complexity:*

Have students cut out fins and test for resistance forces.



Names: \_\_\_\_\_

### Group Questions and Procedures

In your group, complete the following:

1. What is the first thing you think of when you hear the word *aerodynamic* and where did you hear the term before?

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2. Using the resources on the Internet or at your library, find information on aerodynamics and the importance of the use of wind tunnels. Give several examples.

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3. What is *drag* as it relates to aerodynamics?

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- a. What are some things that can be done to an object to decrease its drag?

- b. What are the parts of a rocket that may cause drag?

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4. Cut out three different nose cone shapes on cardstock using the nose cone patterns. Assemble the nose cones using tape or glue, and tape to the paper towel tubes.

5. List the variables that need to be controlled in this activity. (Things that must be the same in each test.)

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6. Use the provided blower to force the rocket backwards. This should be done on a narrow track to keep the rocket in line with the wind. (Books may be lined up to make this track.) Place the nose cone design in front of a leaf blower, as shown in Figure 2. Turn the blower on until the nose cone stops moving.

7. Measure the distance the rocket traveled backwards.

8. Record results on the *Nose Cone Data Table* handout.



Figure 2



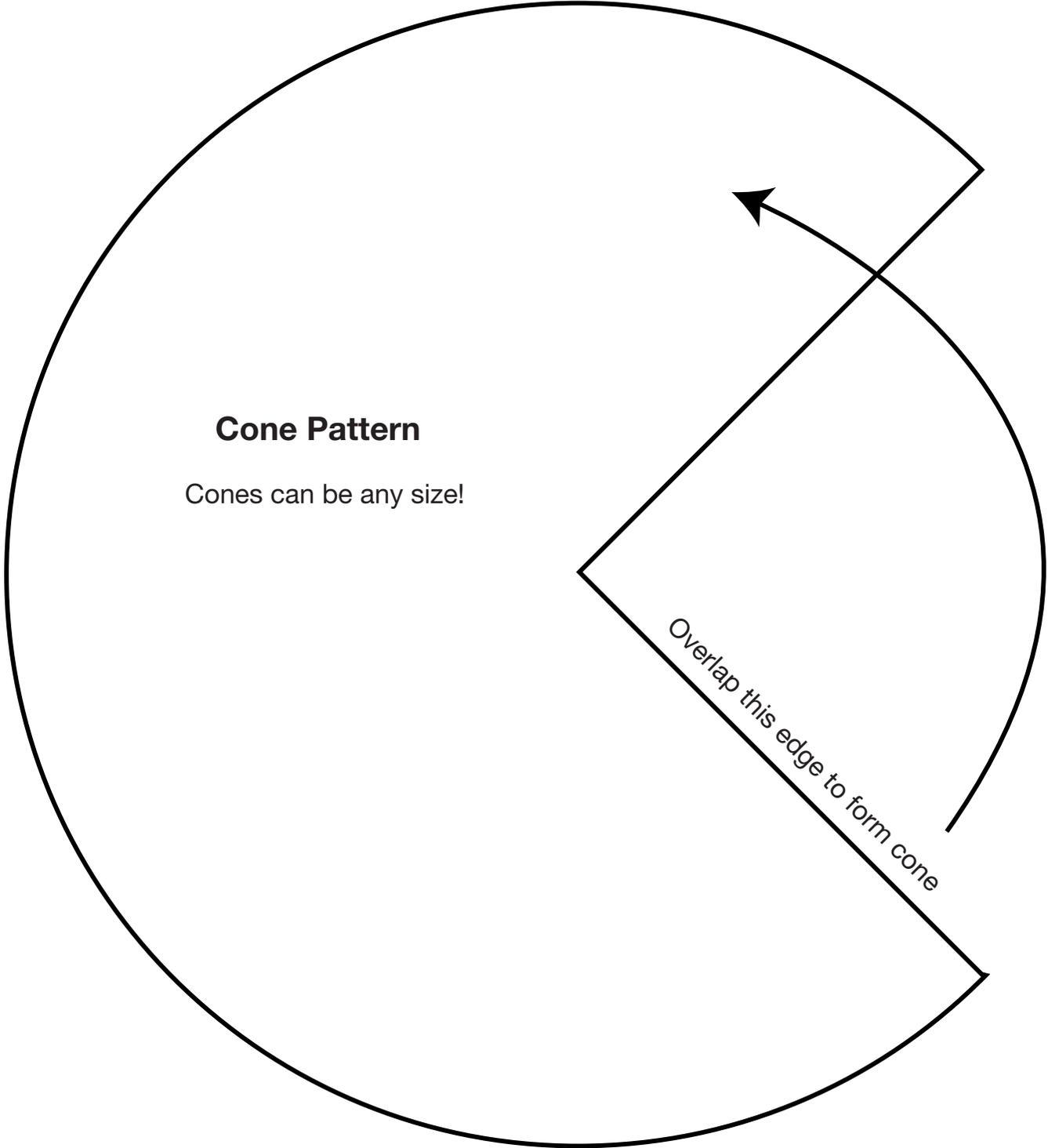
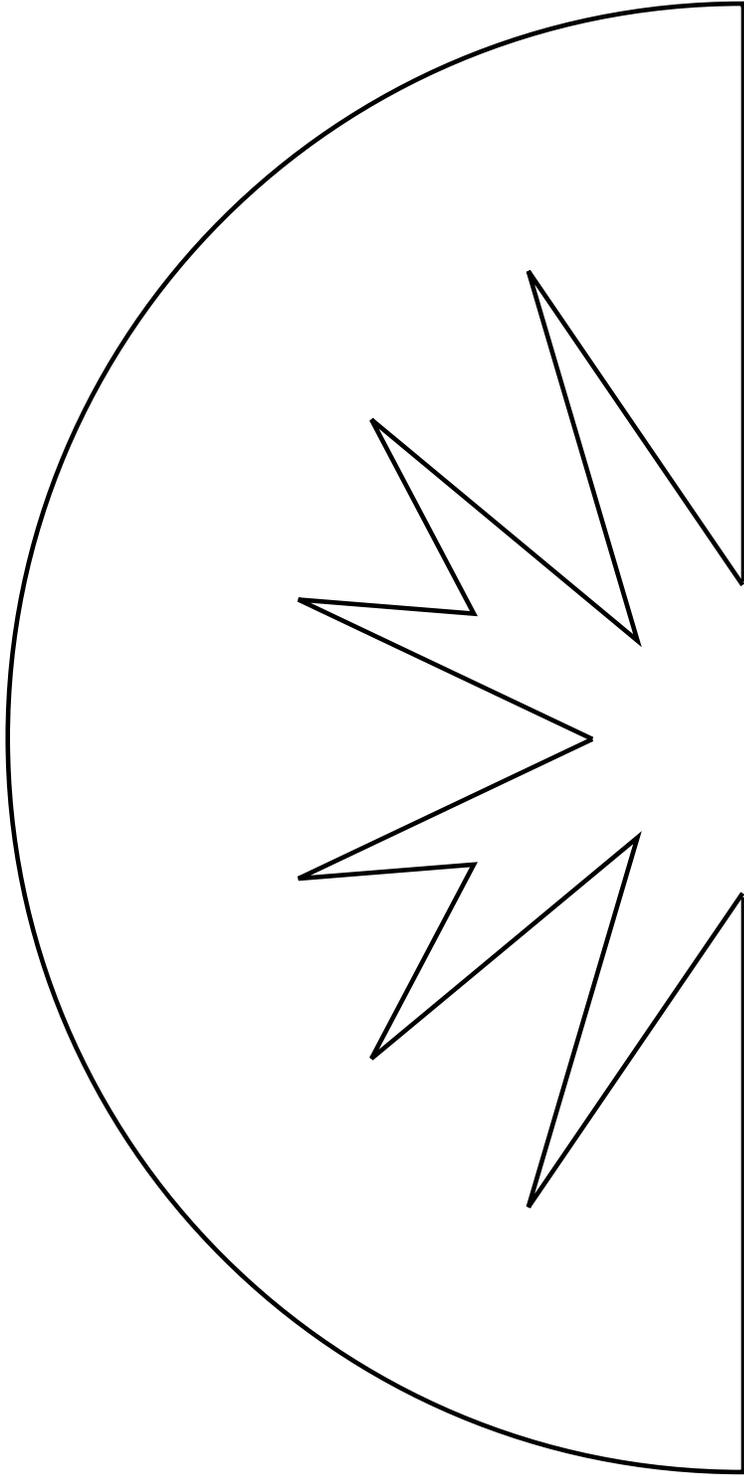


Figure 3



THE NOSE CONE EXPERTS



Cut along the lines. Tape the sides of the triangles together starting with the smaller triangles.

Figure 4



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

**Nose Cone Data Table**

Nose Cone Shape	Distance Traveled			
	Trial 1	Trial 2	Trial 3	Average

**Questions**

1. Which design do you think caused the least amount of drag? Why do you think this?

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2. What data do you have to support your conclusion?

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**3...2...1...Puff!**

**Grades 6 to 8**

INQUIRY-BASED ACTIVITY

## 3...2...1...PUFF!

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1 hour

### About This Activity

In this activity, which was taken from the NASA Rockets Educator Guide, students will construct paper rockets, determine their flight stability, and launch them by blowing air through a drinking straw.

### Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

### Learning Objective

Learners will

- Construct and fly small paper rockets and understand how to stabilize their rockets as they fly

### Materials

- 8.5 x 11 paper (white or colored)
- Transparent tape
- Scissors
- Ruler
- Meter stick or tape measure
- Fat round pencil or dowel
- Safety goggles
- Drinking straws
- Student handouts

## Background

Rocket stability is an important issue for rocket scientists. If a future NASA Space Launch System (SLS) rocket gets into the wrong orbit in space, it may not have enough fuel or supplies to rendezvous with the International Space Station or an asteroid.

Stability means making sure the rocket follows a smooth path in flight. If the rocket wobbles, the ride will be rough and extra fuel will be burned to get back on course. If the rocket tumbles, it will be time to push the destruct button, because a rocket out of control is dangerous. It is relatively easy to ensure stability when traveling through the atmosphere if the rocket's center of mass (COM) and center of pressure (COP) are kept in mind.

COM is the balance point of a rocket and is easy to demonstrate. Think of it like balancing a meter stick on an outstretched finger. If the stick rests horizontally, the COM is directly over your finger. If the stick tips to the right, the COM is to the right of your finger. If the stick tips to the left, the COM is to the left of your finger.

When an object is tossed into the air, it rotates around its COM. Rockets also try to rotate around their COMs while in flight. When rockets rotate they become unstable. This is where COP comes to the rescue.

COP also deals with balance. It is the point where the pressure exerted on the rocket surface by air molecules strikes it as it flies through the air. The COP is a midpoint for the air pressure on the rocket body. On a stable rocket, the COP is located towards the rear and the COM is located towards the front. To understand why the rocket is stable, let's take a look at a couple of devices that also depend on COM and COP.

A weather vane pivots on a vertical axle (COM) when the wind blows. One end of the vane is pointed and the other end is wide. When the wind blows, the wide end of the vane catches more air (more air pressure) and is blown downwind. Less pressure is exerted on the narrow end of the vane and it points into the wind.

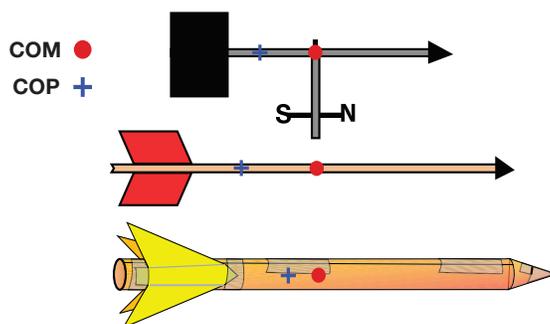


Figure 1. The positions of COM (red dot) and COP (blue +) are shown for a weather vane, arrow, and rocket. The center of pressure is to the rear of the center.

One end of an arrow is tapered to a point, while the other end is not tapered and has large feathers or plastic fins attached to it. In flight, greater air pressure is exerted on the end with feathers or fins than on the end with point. This keeps the arrow from tumbling around its COM and on course to its target.

In both examples, there is more surface area on one side of the COM than on the other. Both devices are stable. Stability of a rocket is the same thing.

## Procedure

### Step 1

Measure out a launch range for students to launch their rockets.

### Step 2

Demonstrate the construction technique for making the paper rockets as shown in Figures 2 to 4. Print out the *How to Build a Paper Rocket* handout and give to students.

- Cut a strip of paper for the rocket body (about 4 cm wide by 28 cm long).
- Use a pencil as a form and roll the strip of paper around the pencil but not too tight that the pencil cannot come out.
- Tape the paper at the ends to hold the tube together, and remove the pencil.
- Close off one end to make a nose cone and tape shut.
- Cut out three or four fins. Tape the fins to the open (lower) end of the rocket. Bend them outward to space them equally.

### Rolling Rocket Tubes

Use 4 x 28 cm strips of paper.

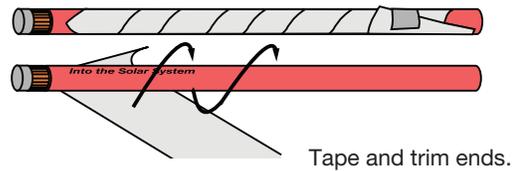


Figure 2

### Making Nose Cones

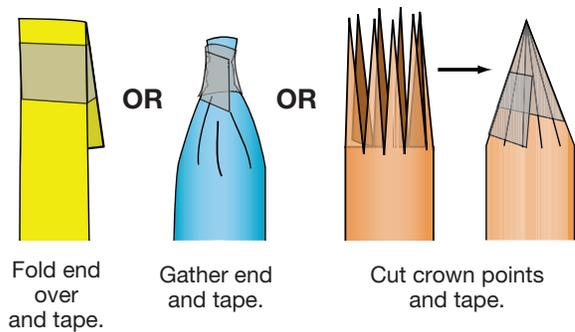


Figure 3

### Making and Attaching Fins

Cut tabs and spread.  
Tape tabs to rocket tube.

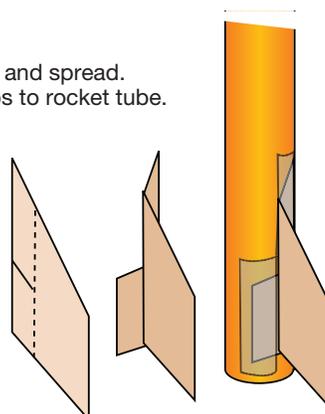
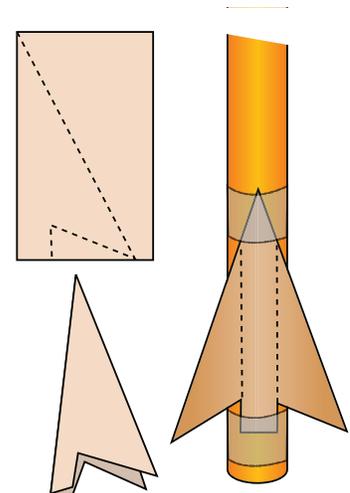


Figure 4

Fold paper square.  
Cut out fins.  
Spread fins and tape to rocket tube.  
Bend fin tips outward.



### **Step 3**

After students construct their rockets, demonstrate how to perform drop tests to check for stability. Hold the rocket horizontally at eye level and drop it to the floor. If the nose of the rocket hits the floor first, the rocket is stable and ready for flight. If the rocket falls horizontally or the fin end hits first, the rocket is unstable.

Larger fins may be needed to stabilize the rocket. Have students perform their own stability tests and make adjustments to their rockets.

### **Step 4**

Demonstrate the rocket launch procedure. Stand at one end of the launch range. Insert a straw into the rocket body. Aim the rocket down range and blow forcefully into the straw. Liftoff!

### **Step 5**

Have students put on their safety glasses, then discuss safety and the importance of wearing safety glasses. Explain that no other students should be launching when rockets are being retrieved from launch range.

### **Step 6**

Have students hold distance trials to improve their rocket design. Students will launch their rocket three times and calculate the average distance the rocket traveled. They will then try to improve their design to get greater distance. The 3...2...1...Puff! *Paper Rocket Data Sheet* handout outlines the procedures and provide space to jot down and analyze data.

## **Suggestions for Differentiation**

Below are additional strategies to differentiate instruction based on student readiness.

#### *Support:*

Pre-cut the fins.

#### *Complexity:*

Have students experiment with changing fin shapes and sizes to investigate the effects on their rockets performance.



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

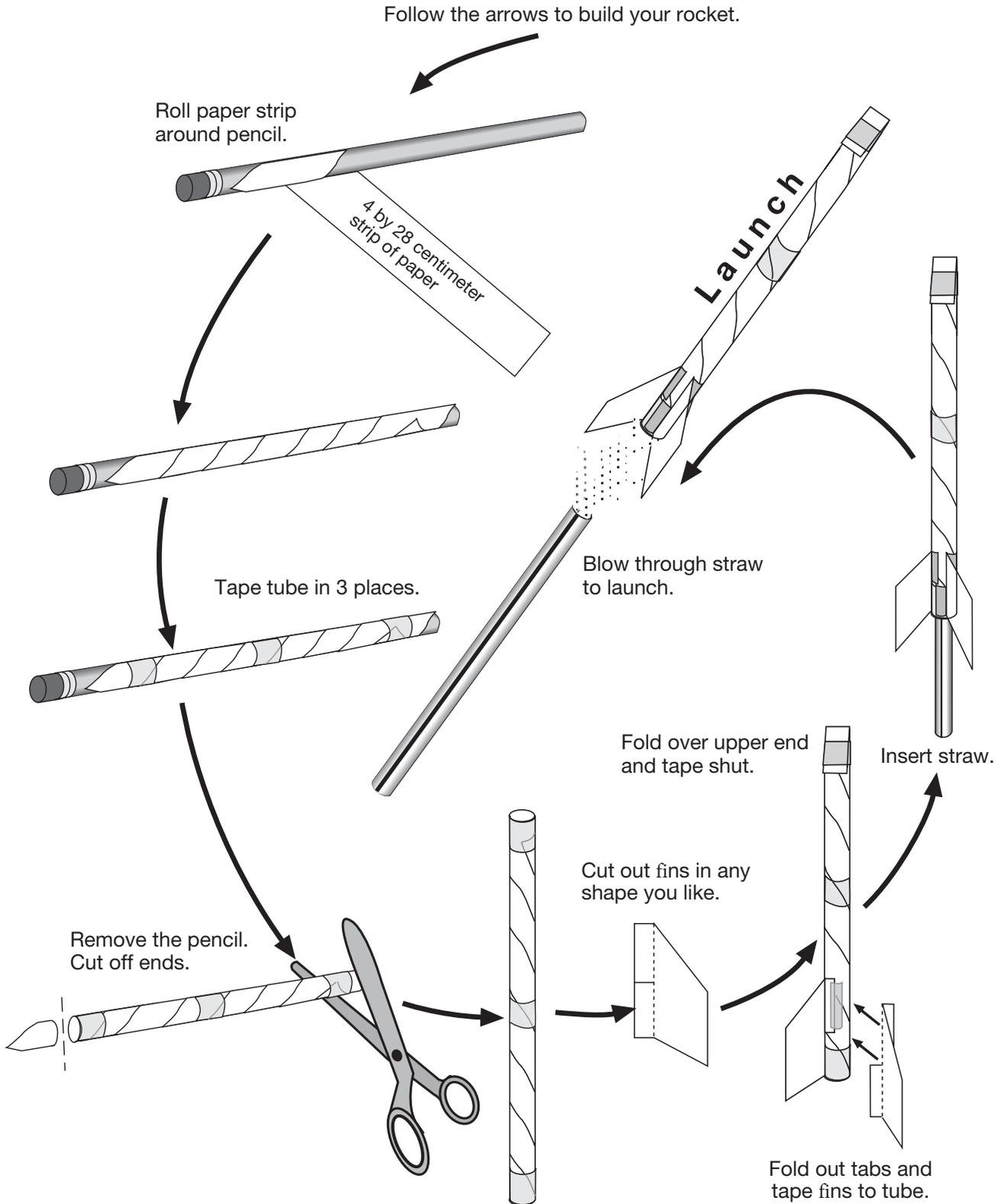
### Paper Rocket Data Sheet

1. Launch your rocket three times at the same launch angle. Measure how far it flew each time and record measurements in the data table below under the space labeled "Rocket 1." Calculate the average distance for the three flights.
2. What can you do to improve the distance your rocket travels? (Answer in the notes section.) Design and build a new rocket. Predict how far it will fly, record under "Rocket 2." Launch second rocket three times and measure distance traveled and record data. Calculate difference between predicted and actual distance? Did Rocket 2 fly farther than Rocket 1? Write answers below in the notes section.
3. Design and build a third rocket. Fly it the same way you did for Rockets 1 and 2. Did Rocket 3 fly farther than Rocket 2? Write answers below in the notes section.
4. On the back of this paper, write a short paragraph describing the improvements made to your rockets, how well they flew, and what you can conclude from your experiments. Draw pictures to illustrate how each rocket looked.

Rocket 1		Make notes about the flight here.	
Flight Distance (in cm)			
Flight 1			
Flight 2			
Flight 3			
Average Distance			
Rocket 2		Make notes about the flight here.	
Flight Distance (in cm)			
Flight Distance Prediction (in cm)			
Flight 1			
Flight 2			
Flight 3			
Rocket 3		Make notes about the flight here.	
Flight Distance (in cm)			
Flight Distance Prediction (in cm)			
Flight 1			
Flight 2			
Flight 3			



## How to Build a Paper Rocket





# Pop! Rocket Launcher and Pop! Rockets

**Grades 6 to 8**

INQUIRY-BASED ACTIVITY

# POP! ROCKET LAUNCHER AND POP! ROCKETS

Grades: 6 to 8   Prep Time: 2 hours   Activity Time: 1.5 hours

## About This Activity

In this activity, which was taken from the NASA Rockets Educator Guide, students will stomp or jump on an empty 2-liter soft drink (“pop”) bottle and force the inside air out through connected plastic pipes to propel a paper rocket.

## Next Generation Science Standards

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

## Learning Objective

Learners will

- Design, construct, and launch paper rockets

## Materials

- Empty and rinsed 2-liter plastic soft drink bottle
- Two ½-in. PVC tee connectors
- One ½-in. PVC connector
- Two ½-in. PVC caps
- One 6 ft length of ½-in.-diameter PVC pipe
- Duct tape
- Ruler
- Eye protection for anyone near launcher
- Cardstock paper
- Glue stick
- Transparent tape
- Scissors
- Crayons or colored markers
- Ruler
- Pop! Rocket Launcher Pattern
- Penny
- Measuring tape or rulers
- Student handouts
- Optional: PVC cutter
- Optional: Computer with an illustration program and printer

## Background

### About the Launcher

Obtain all the PVC parts and use a fine-tooth saw or a PVC cutter to cut into the correct lengths. When putting the pieces together, no glue is needed because friction will hold the parts with occasional adjustments. Leave the label on the bottle. This gives students a target to aim for when stomping. If the end of the bottle is accidentally squashed, the bottle becomes difficult to reinflate and has to be replaced. Aim the launch rod at different angles by tilting to one side or another. Rotating the entire launcher horizontally changes its direction.

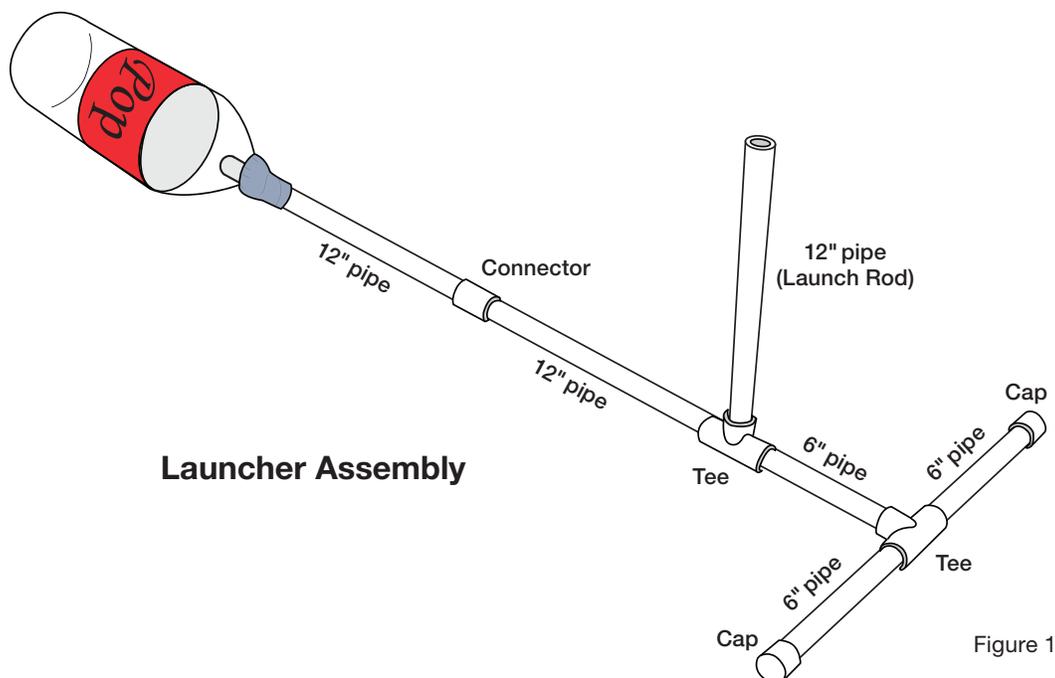
### About the Rocket

A rocket with a triangular cross section is made from three rocket-shaped strips of cardstock paper and launched with the Pop! Rocket Launcher. Students can customize their rocket fin shapes and decorate the rockets. An alternative single-piece Pop! Rocket is also explained.

## Procedure

### Step 1—Constructing the Launcher

- Obtain all materials listed on the materials list.
- Cut the PVC pipe as follows: 4 pieces 12" long and 3 pieces 6" long.
- Insert the end of one 12" pipe a few inches into the neck of the bottle and tape it securely with duct tape. There will be an extra 12" pipe to construct a second stomp section for convenience.
- Assemble the launcher as shown in Figure 1.

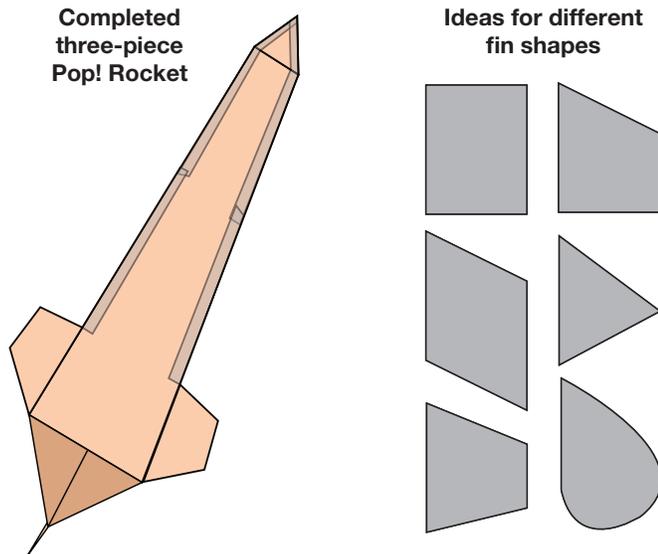


## Step 2—Using the Pop! Rocket Launcher

- In an open space, place the launcher on the ground, tilt the launch rod in the desired direction, and slide the rocket onto the launcher. If there is a light wind, aim in the direction of the wind. If shooting at targets, have each student aim the launcher for his or her flight.
- Make sure the landing zone is clear of anyone who might be hit by the rocket.
- Have the launching student or any students near the launcher put on eye protection and count down to zero.
- Have the student stomp or jump on the label of the bottle. This will force most of the inside air out of the bottle through the tubes and launch the rocket.
- While the student is retrieving the rocket, reinflate the 2-liter bottle. Separate the bottle from the launcher by pulling it from the connector. Wrap your hand around the pipe end to make a loose fist and blow through the opening into the pipe to keep your lips from touching the pipe. When you reconnect the bottle to the launcher, it is ready to go again.
- When the landing zone is clear, have the next student put on the goggles, slide the rocket onto the launcher, aim the launcher, count down, and stomp on the bottle.

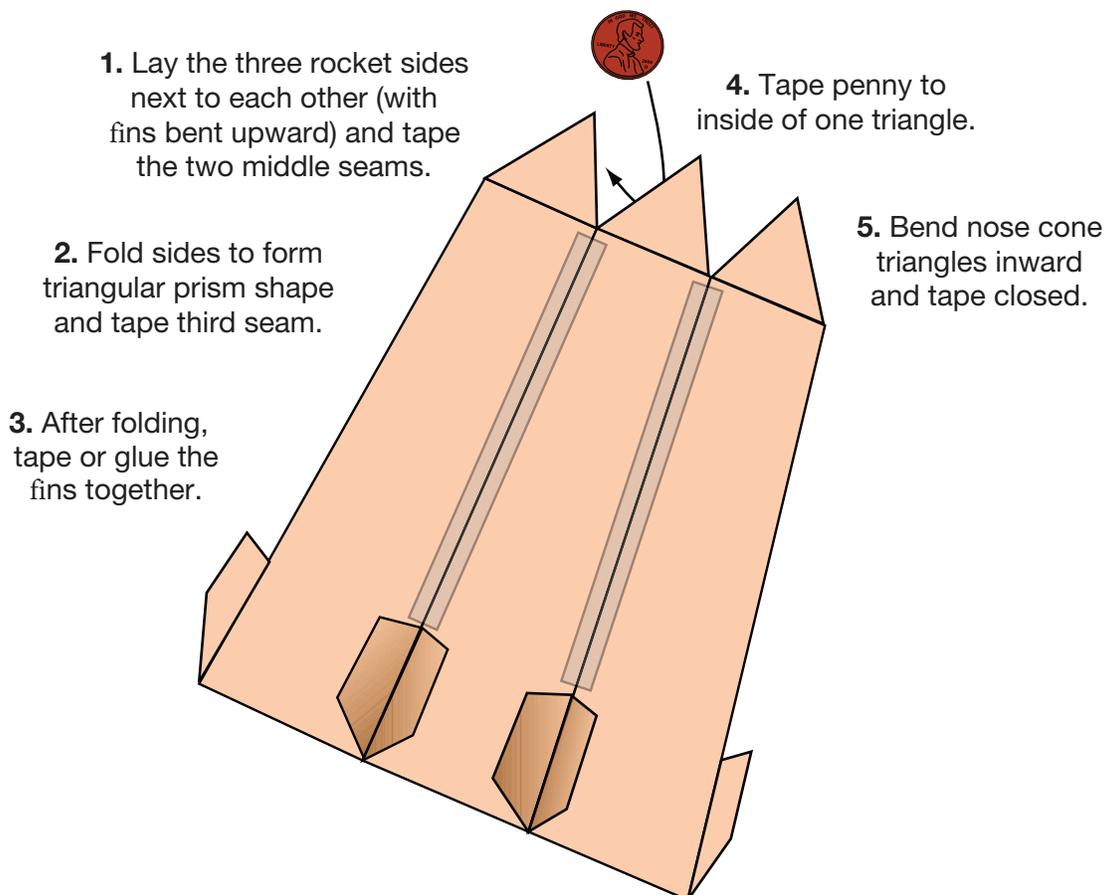
## Step 3—Construction Directions

- Demonstrate the construction procedures for the three-piece and one-piece rocket templates provided.
- Have each student construct either the three-piece or one-piece rocket from the templates.
- Have students test their rocket twice, and add data to their student handout sheets.
- Have students design and construct their own rocket.
- Students should test their design at least twice and add data to their student handout sheets.
- Have students make one revision to their rocket design and retest twice.



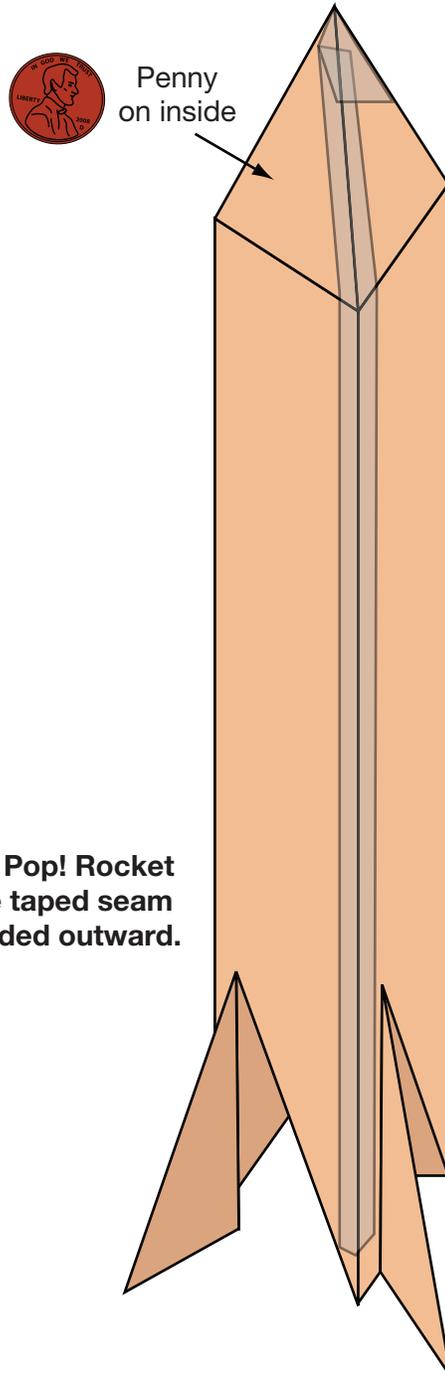
**Step 4—Three-Piece Pop! Rocket Construction**

- a. Give each student the three-piece rocket pattern on cardstock paper. Students can add decorations to their rockets.
- b. Cut out the three pieces and press the edge of a ruler to the fold lines for the fins and nose cone to get a straight fold. Fold the fins outward.
- c. Tape a penny securely to the inside of one of the nose cone triangles.
- d. Slide the pieces together and match up the sides of the rocket body. Run a strip of tape along the seams. Do not tape the fins or nose cone pieces yet.
- e. Pick up the rocket, bring the two side pieces together, and tape the seam. It may be helpful to insert the PVC pipe into the rocket before taping.
- f. Use glue stick or tape to join adjacent fins pieces together to make three fins. If desired, make six fins by not taping the fins.
- g. Push the PVC pipe inside the rocket body up to the nose cone. Fold the three triangles inward and tape the seams.
- h. The rocket is ready for launch.



### Step 5—One-Piece Pop! Rocket Construction

- a. Print the pattern for the one-piece rocket on cardstock paper.
- b. Use a ruler and the edge of a penny to score the fold lines by placing the ruler along a dashed line and running the edge of the penny (held at an angle) across the paper to make a small groove. The groove will ensure that the fold line is accurate and straight.
- c. Cut out the pattern on the solid lines.
- d. Tape a penny to the inside of one of the nose cone triangles.
- e. Fold the three rectangles into a triangular prism shape with the large tab inside. Tape the seam.
- f. Fold the triangles inward to form the nose cone. The tabs should be inside. They will provide support for taping.
- g. Bend the fins outward. The rocket is ready for launch.



**One-piece Pop! Rocket with single taped seam and fins folded outward.**

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

### Directions

1. Follow the directions provided by your instructor to make a one-piece or a three-piece Pop! Rocket.
2. Test your rocket twice and record the distance flown in the chart below.
3. Design and construct another rocket using information you've learned from constructing the first rockets. Your goal is to have your rocket fly the farthest. Draw your design below.
4. Test your design and record the distance in the table below.
5. Revise your design and launch it twice. Record the distance in the table below.

Rocket Type	Distance Flown Trial 1	Distance Flown Trial 2
Pop! Rocket		
Your Rocket Design		
Your Revised Design		

### Your Rocket Design

1. What changes did you make to your second design? Write or draw below.

2. Of the three rockets, which rocket flew the farthest?

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3. What design elements influenced the distance of the rocket?

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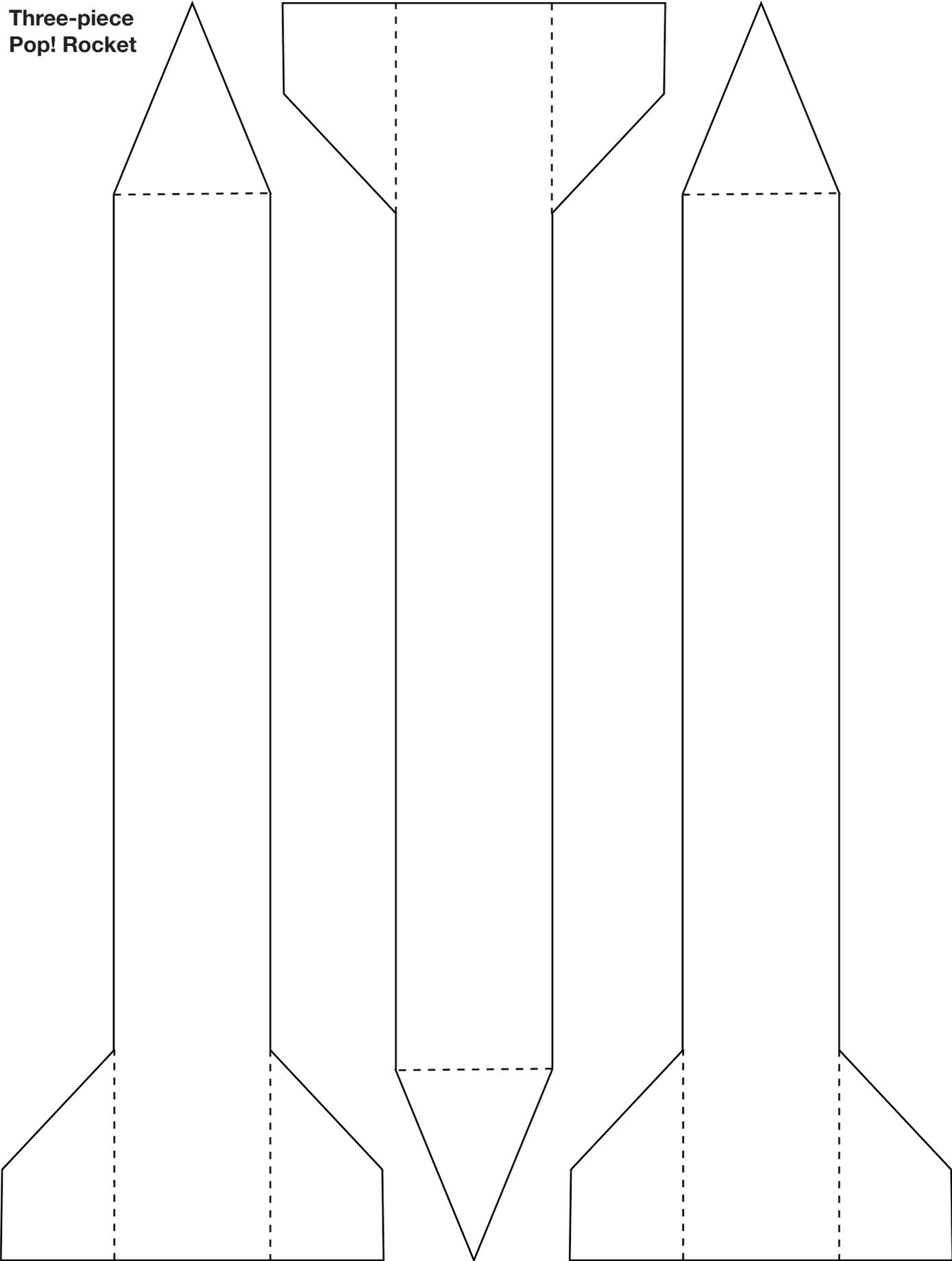
4. If you could redesign your rocket again, what changes would you make to improve its performance?

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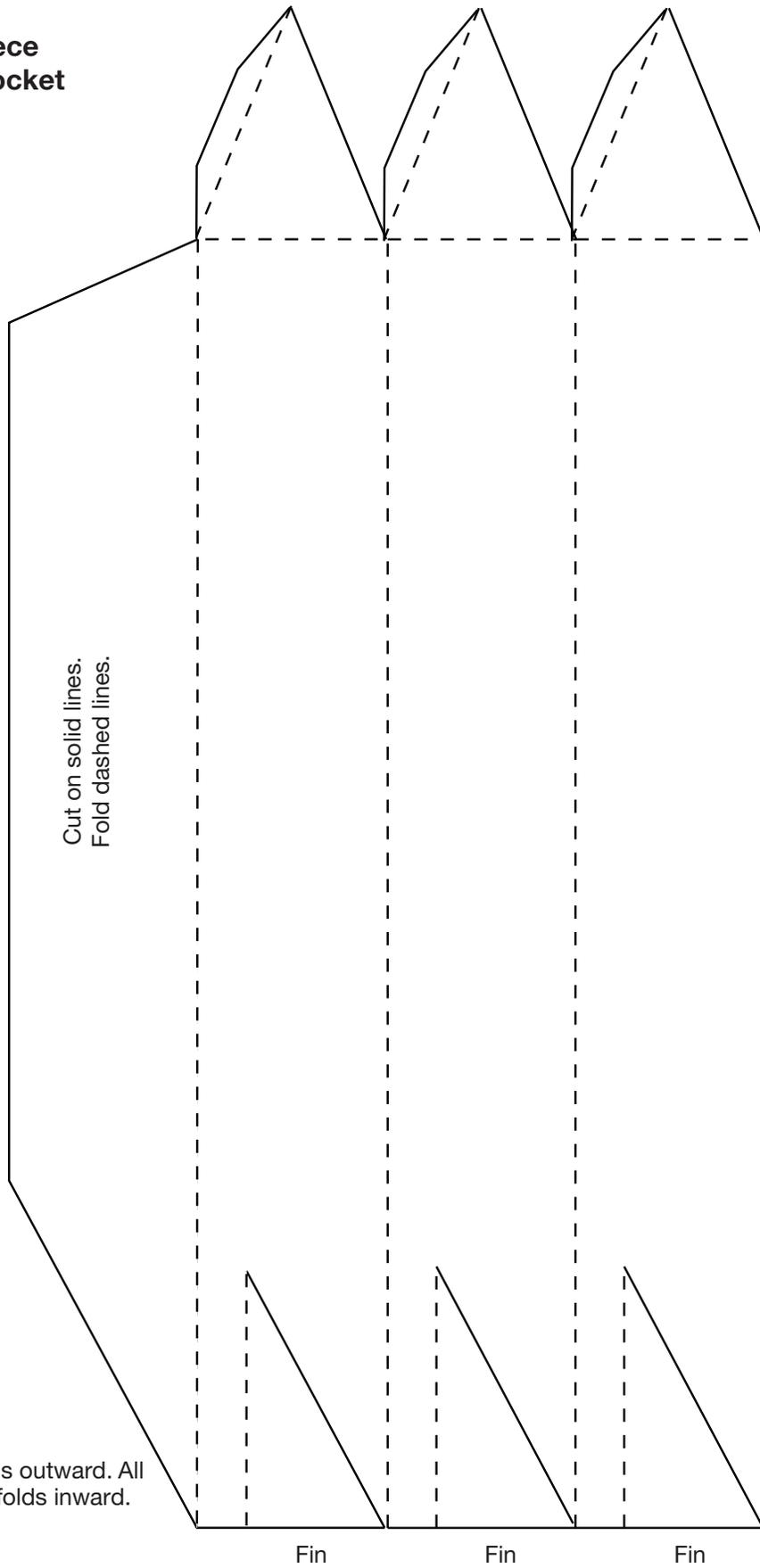
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**Three-piece  
Pop! Rocket**





**One-piece  
Pop! Rocket**



Cut on solid lines.  
Fold dashed lines.

Fold fins outward. All  
other folds inward.

Fin

Fin

Fin







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