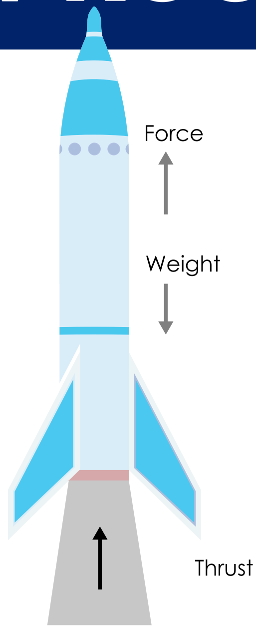
TEACHER GUIDE

# FORCES AT WORK: NEWTON'S LAWS OF MOTION WITH STRAW ROCKETS




A body in rest or in motion will remain in its position with a constant velocity unless acted upon by a force.

## MATERIALS PER GROUP:

The materials for each activity will vary. See each lab for more specific information.

For all rockets, each student or student team will require:

- Straw(s)
- Paper for fins
- Paper for nose cone
- Masking or scotch tape

Each launch group will require:

- Launcher (per group of two to three students)
- 15-foot tape measure
- Tape to secure measuring tape to floor or table

Materials that may be needed:

- Electronic balance
- Modeling clay
- Stopwatch

## SAFETY PRECAUTIONS:

- Use caution when using scissors.
- Wear safety glasses when launching rockets.
- Be sure no one is in the path of the rocket during launch. Teacher may want to designate specific launch ranges within the classroom or area used.

## TOTAL DURATION:

Three to seven class periods

## LESSON OVERVIEW:

One of the most basic scientific concepts is the interaction between forces and matter. Forces are observed around us in our everyday lives from the gravity keeping us on the ground to the wind blowing through the trees. There are only a five forces that are known to science. The first three — gravitational, electrical, and magnetic — are the forces that are most easily observed. The second two — nuclear and weak interaction forces — occur within the nucleus of an atom and are therefore, not observable to most people. While having a basic understanding of forces is important for your science grade, it is also important for your safety.

## LESSON OBJECTIVES:

Students will be able to:

1. Design and construct a rocket to travel the farthest distance.
2. Evaluate the effectiveness of design to meet goal.
3. Explain how Newton's laws of motion apply to real world scenarios.

## ESSENTIAL QUESTION:

What forces exist around us?

## TOPICAL ESSENTIAL QUESTION:

How can Newton's laws of motion be applied to everyday life?

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## STANDARDS:

**MS-PS3-1**
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass and speed of an object.

**MS-PS3-2**
Develop a model to demonstrate that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored within the system.

**MS-PS3-6**
Construct, use and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

**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.

**Science and Engineering Practices:**

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

**Crosscutting Concepts:**

1. Patterns
2. **Cause and Effect: Mechanisms and explanations**
3. Scale, Proportion and Quantity
4. Systems and System Models
5. **Energy and Matter: Flows, cycles and conservation**
6. Structure and Function
7. **Stability and Change**

## KEY VOCABULARY:

Force
Thrust
Kinetic Energy
Inertia
Drag
Potential Energy
Mass
Lift
Acceleration
Weight

## LAB BACKGROUND INFORMATION:

One of the most basic scientific concepts is the interaction between forces and matter. Forces are observed around us in our everyday lives, from the gravity keeping us on the ground to the wind blowing through the trees. Only five forces are known to science. The first three – gravitational, electrical and magnetic – are the most easily observed. The second two – nuclear and weak interaction forces – occur within the nucleus of an atom and are therefore not observable to most people. While having a basic understanding of forces is important for your science grade, it is also important for your safety.

The work of Sir Isaac Newton and his predecessor Galileo form the basis of the field of kinematics, or the study of motion. Newton formed his first law of motion from the work of Galileo, who introduced the idea of inertia. Inertia is the tendency of a body to resist a change in its motion. For example, if a ball is at rest, it will stay at rest. If the ball is in motion, it will stay in motion. Newton's first law of motion states: A body continues in its state of rest, or of uniform motion in a straight line, unless it is acted upon by an unbalanced external force. With the ball example, if a ball is at rest, it will stay at rest until a force acts on it (e.g., kick). If the ball is in motion, it will continue in a straight line until it is acted upon by a force. We know that ball will not keep moving forever if we were to try this experiment. What stops it? The force of friction, or the interacting forces of the ball and the pavement.

Newton's second law of motion explains the relationship between force, mass and acceleration. It states that the force acting on an object is equal to the mass of the object times its acceleration. In other words, as the force applied to the object increases, the acceleration will increase. It also relates to mass. As the mass increases, the amount of force needed to accelerate the object increases.

Newton's third law of motion states that every action has an equal and opposite reaction. This means that forces always act in pairs. First an action occurs – say you lean against a wall. Then there is an equal and opposite reaction from the wall as it presses against you. Another example: the action when a gun is fired and the expanding gas pushes the bullet forward. The equal and opposite reaction causes the gun to move backward with the same force.

In addition to Newton's laws, the rockets can be used to demonstrate potential and kinetic energy. Potential energy is the energy an object has because of its position relative to other objects, or stored energy. When the plunger is held up, it has potential energy. When the plunger falls, it is creating kinetic energy. Kinetic energy is the energy an object has because of its motion. The plunger condenses the air in the tube, creating an increase in air pressure that is transferred to the rocket as it leaves the launcher. Kinetic energy is proportional to mass, meaning that if the mass is doubled, then kinetic energy doubles. In other words, if two objects move with the same speed, the more massive one has the higher kinetic energy. Kinetic energy is also affected by the velocity, or speed, of the object. In this case, kinetic energy is squared, not proportional.

Where can we see Newton's laws in everyday life? Perhaps you've ridden in a car before. Have you ever wondered why there are seat belts in your car? Cars haven't always had them! Think about Newton's first law. When the car stops, does everything else in the car stop too? No, they resist any change to their motion until something stops them. Hopefully, this is a seat belt. If not, it could be the steering wheel or windshield.

Newton's second law also applies, as the greater mass an object has, the longer it takes to accelerate. It also takes the same object longer to decelerate or stop. Understanding this is critical when it comes to sharing the road with large semitrucks. These trucks have significantly more mass than a car. As a result, a car may take only a few hundred feet to stop, while the semi will require significantly more distance, especially if it is loaded. The semitruck also has more kinetic energy, which is transferred to whatever object is in front of it if it can't stop in time. Kinetic energy is also affected by the velocity of the object. The faster the object is traveling, the more kinetic energy it has!

This has serious implications for people traveling on roadways. If a car stops suddenly in front of a semi, the truck is going to take longer to stop, potentially causing an accident. And remember that trucks carry cargo. Does the cargo stop because the truck stops? No, it will continue forward until it is acted on by another force, in this case the front of the trailer, propelling the trailer and thus the truck forward into whatever is in front of it. Now imagine that load in the trailer was live animals such as horses or cattle. The event could have a very tragic ending.

The same can be said for rural roads and large agricultural implements. While the tractor may be moving slowly, the car that is approaching from the rear is traveling fast. Most people have trouble estimating how slow a vehicle is moving when they are traveling at high speeds. This causes many drivers to misjudge the distance between the tractor and themselves, leading to serious accidents.

## INTRODUCTION:

Straw rockets can be a fun method of demonstrating Newton's Laws of Motion. This lesson is versatile in that it can be done by individual students or student teams and includes six labs that can be done as stand-alone activities or can build upon each other. The teacher's guide includes an explanation of how each lab illustrates Newton's law(s) of motion.

## ENGAGE:

These are suggested activities to engage students with the three laws of motion. Dynamic carts are an easy way to demonstrate the laws of motion. These can be obtained from science supply stores or made using blocks of wood with wheels added and a spring-loaded dowel at one end. After conducting each demonstration, give students time to answer their engage questions.
To demonstrate Newton's first law of motion, place the cart on the desk/floor and leave it be. The cart will stay in that spot until it is acted upon by another force (push with hand).

To demonstrate Newton's second and third laws of motion, cock the spring on one of the carts and place the front ends of the two carts together. When everyone is watching, depress the release button on the first cart and watch the two carts move away from each other. This demonstrates that every action has an equal and opposite reaction (third law). Students can use a measuring tape to measure the distance the carts travel.
To demonstrate Newton's second law, add mass (textbooks work well) to one of the carts and repeat the demonstration. Students will observe that the more mass on the cart, the less distance it will move. Students should infer that the greater the mass, the less acceleration the cart has. Or the more mass, the less the force affects the cart.

Student engage questions:

1. How does the first demonstration show Newton's first law of motion?

2. Explain how Newton's third law of motion is shown in the second demonstration.

3. What happens in the third demonstration when mass is added to one of the carts? How does this demonstrate Newton's second law of motion?

4. Name two examples of how Newton's laws of motion can be seen in the world around you every day.

## EXPLORE:

**Introduction:**

Straw rockets can be a fun method of demonstrating Newton's laws of motion. This lesson is versatile in that it can be done by individual students or student teams and includes six labs that can be done as stand-alone activities or can build upon each other. The teacher's guide includes an explanation of how each lab illustrates Newton's laws of motion.

**Lab 1: Effect of Launch Angle on Distance**

Students construct one rocket and launch at three different angles to determine the best angle to send the rocket the greatest distance.

**Lab 2: Effect of Launch Force on Distance**

Students construct one rocket and launch at three different forces to determine which force produces the farthest distance traveled.

**Lab 3: Effect of Mass on Distance**

Students construct one rocket to which they will add modeling clay twice to add mass and determine the effect of mass on the distance traveled.

**Lab 4: Effect of Nose Cone Design on Distance**

Students design and construct three rockets to test the effect of nose cone design on distance traveled.

**Lab 5: Effect of Fin Design on Distance**

Students construct three different rocket fin designs and test the effect of fin design on distance traveled.

**Lab 6: Measuring Velocity**

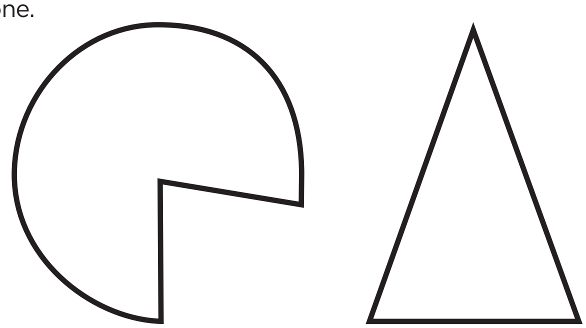
Students construct one rocket to test at differing launch forces to calculate velocity of the rocket.

**Construction of Rockets:**
The three main components of the straw rockets are the nose cone; the fuselage, or body of the rocket; and the fins. The nose cone of the rocket is designed to make the air flow smoothly around the rocket, reducing aerodynamic drag (air friction). The body tube of the rocket is the airframe, to which the other components are affixed. The fins of the rocket provide aerodynamic stability during flight, enabling the rocket to fly straight. The number, placement and shape of the fins can vary.

For these labs, students should use the straw as the body tube when building their rockets. For labs 1, 2, 3 and 6, students will construct one rocket. While the design of the rocket should be left to the ingenuity of the students, the teacher should set the parameters of design. For example, require that all rockets have a nose cone or specific number of fins. For labs 4 and 5, the students should design three rockets that differ in the variable tested (mass, nose cone design, fin design). However, all other components not being tested need to be identical on each rocket.

For this lesson, students will need to use narrow-diameter (normal-sized) drinking straws. If using bendable straws, students will need to cut the bendable elbow off to use only the straight part of the straw. Teachers may also have pre-cut paper (circles of different sizes, 2- to 3-inch squares of paper) available to reduce the waste of paper and shorten the amount of time students need to build their rockets. See below for tips on creating nose cones. It is also beneficial if students have their own scissors and rolls of tape.

**Creating the nose cone.**
There are different methods for creating a nose cone, and one of the labs asks students to create their own designs. However, a simple method for creating a fairly uniform nose cone is shown below. Using a round piece of paper, cut out a pie-shaped piece from one side. Overlap the edges of the cuts, and the paper can then be rolled to form a cone.



**Tips for Success:**
- To maximize the launchers, teachers can create launch groups of three to six students depending on class size.
- For a more accurate measure of distance traveled, have one or two students in the launch group stand near the measuring tape when the rockets are launched. This way they can see where the rocket lands and provide a more accurate distance reading.
- It is recommended to use the launchers in a large open space such as a gymnasium or hallway. The launcher can send rockets upward of 25 feet. This activity can be done outside; however, the wind can add another variable to the experiment.

**Newton's Laws of Motion Applied to Straw Rockets:**

Newton's laws of motion can be applied to the straw rockets. The first law is demonstrated as the rocket sits on the launch tube; it is in a state of inertia. The rocket won't move until the force of the air creates an unbalanced force. The rocket will continue its flight until the friction of the air and the force of gravity create an unbalanced force that changes the flight of the rocket. The second law of motion is demonstrated by the amount of force applied and the mass of the rocket. The height that the plunger is dropped from will determine the amount of force (air pressure) applied to the rocket. The greater the height, the greater the force exerted on the rocket. How much the rocket accelerates (distance traveled) will be determined by the mass of the rocket. The greater the mass, the less distance traveled. Newton's third law of motion is demonstrated as the plunger is dropped and the air is compressed beneath it. This rapidly forces air into the launch tube. The nose cone of the rocket traps the air, and for a brief moment it is equal to the force of gravity pushing it down. When the air pressure inside the straw rises (action), it causes the rocket to take off (reaction).

## LAB 1: EFFECT OF LAUNCH ANGLE ON DISTANCE:

**Instructions**

In this lab you will be evaluating the effect of the angle of launch on the distance traveled by your rocket. You will need to construct one rocket to be used for all three tests. Be sure your rocket includes a nose cone and fins.

**Part 1: Testing your rocket**

You will launch your rocket at three different angles while maintaining the same launch force to determine the best angle for distance. Conduct three launches and average the distance to get your results.

**Table 1: 20° Angle Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 20° | 4 | |
| 2 | 20° | 4 | |
| 3 | 20° | 4 | |
| Average | | | |

**Table 2: 24° Launch Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: 70 ° Launch Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 70° | 4 | |
| 2 | 70° | 4 | |
| 3 | 70° | 4 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch angle and distance traveled by using your averages from each angle. Be sure to label your axes and provide units where needed.

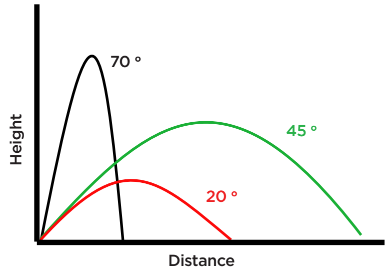
**Part 3: Evaluation Questions**

1. How does changing the angle influence distance traveled?
**The higher the angle of launch, the less distance is traveled (greater vertical direction). The lowest angle of launch doesn't travel far because gravity will cause it to fall early.**

2. Which was the best angle of launch?
**45 degrees**

3. What forces were at work on your rocket during this experiment?
**Gravity (weight), thrust (air pressure), drag (air resistance)**

4. Based on the distances traveled and the launch angle, draw a diagram to show what you think the trajectory or flight path looked like for each angle.




5. If you could change the design of your rocket, what would you modify to improve the distance it traveled?
**Answers will vary.**

6. What variables were held constant in this experiment (control)?
**Launcher used, launch force, design of rocket**

7. What variable was changed or modified in this experiment (independent)?
**Angle of launch**

8. What variable was measured in this experiment (dependent)?
**Distance traveled**

**Teacher Notes:**
This experiment is designed to show the effect of gravity on mass. The rocket's speed is the same for all angles, as the amount of force used to propel the rocket remains constant. The only difference is the angle of launch. The launch angle changes the vertical direction (the force or pull of gravity exerted on mass, which gives it weight – weight is the force that gravity exerts on mass). For the higher angles, more force from the plunger is used to overcome gravity, sending the rocket higher (vertical) and leaving less force to move the rocket horizontally. Thus, rockets launched straighter in the air will fly higher but travel less distance.

For the lower launch angles, more force is used to move the rocket horizontally. However, less force is available to overcome gravity, causing the rocket to decrease in vertical position as it moves horizontally.

The best launch angle must balance these forces by giving the rocket enough vertical force to overcome gravity while using all of the available horizontal force to produce distance. The optimal angle for launch is 45 degrees.

To successfully accomplish this experiment, the rocket must not be too light. If it is too light, there will be minimal differences between the 20-degree and 45-degree angles. If more mass is required, wrap additional layers of tape on the straw or use modeling clay as the nose cone.

## LAB 2: EFFECT OF LAUNCH FORCE ON DISTANCE:

**Instructions**

In this experiment, you will be evaluating the effect of launch force on the distance traveled by your rocket. You will use one rocket to conduct all three tests.

**Part 1: Testing your rocket**

You will launch your rocket at the same angle for each test while changing the launch force to determine the best launch force for distance. Conduct three launches and average the distance to get your results.

Table 1: Piston Position 2

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 2 | |
| 2 | 45° | 2 | |
| 3 | 45° | 2 | |
| Average | | | |

Table 2: Piston Position 3

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 3 | |
| 2 | 45° | 3 | |
| 3 | 45° | 3 | |
| Average | | | |

Table 3: Piston Position 5

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 5 | |
| 2 | 45° | 5 | |
| 3 | 45° | 5 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and distance traveled using the averages. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation Questions**

1. Draw a model of the launcher to describe when and where potential energy and kinetic energy occur in the system.

**Potential energy exists when the plunger is in the drawn-back state. Kinetic energy exists when the plunger is in motion.**

2. In this experiment, how were different levels of potential and kinetic energy created?

**Potential energy is created when the plunger is lifted to different heights. Both potential and kinetic energy increase as the plunger is positioned higher in the system.**

3. How much additional distance does each increase in force produce?

**Answers will vary (should show a little less than double the distance).**

4. What is the relationship between additional launch force and distance traveled?
**Greater force produces greater distance.**

5. What forces are acting on your rocket?
**Gravity (weight), thrust (air pressure), drag (air resistance)**

6. If you could change the design of your rocket, what would you modify to improve the distance it traveled?
**Answers will vary.**

7. What variables were held constant in this experiment (control)?
**Launcher, launch angle, rocket design, environment**

8. What variable was changed or modified in this experiment (independent)?
**Launch force**

9. What variable was measured in this experiment (dependent)?
**Distance traveled**

**Teacher Notes:**
Velocity (speed) of an object refers to the rate of motion of an object. Acceleration of an object refers to how the movement (velocity) of the object is changing. In other words, it measures the change in speed of the object. Newton's second law of motion states that force equals mass times acceleration (f = ma). It explains how an object will accelerate (change velocity) if it is pushed or pulled upon by a force. There is a proportional relationship between force and acceleration. If you push a ball, it will accelerate. If you push the ball three times harder, the acceleration will be three times greater. There is also an inversely proportional relationship between the mass of the object and the acceleration. If you are pushing a cart that has five times the mass, it will have one-fifth the acceleration.

In this experiment, students should see a relationship between the amount of force that is applied and the acceleration of the rocket. As the force increases, the acceleration, and thus distance, will increase as well. While students are building only one rocket, as a group they may see that some rockets travel farther than others. They should be able to draw the conclusion that the mass of the rocket will affect the acceleration.

## LAB 3: EFFECT OF MASS ON DISTANCE:

**Instructions**
In this experiment you will be evaluating the effect of the mass of the rocket on distanced travelled by the rocket and, by observation, the acceleration of the rocket. For this experiment you will need to construct one rocket that you will be able add mass to by adding additional modeling clay to your nose cone.

**Table 1: Mass:** ________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 2: Mass:** ________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: Mass:** ________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and distance traveled using the averages. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation questions**

1. How does the mass of the rocket affect the distance traveled?

**The greater the mass of the rocket, the less distance it travels.**

2. What forces are acting on your rocket?

**Gravity (weight), thrust (air pressure), drag (air resistance)**

3 a. Do you think there is anything about the design of your rocket other than the mass that could have affected the distance traveled?

**Answers will vary — leak in the launcher, wind currents, interference from other groups.**

3 b. If you could change the design of your rocket, what would you modify to improve the distance it traveled?
**Answers will vary.**

4. What variables were held constant in this experiment (control)?
**Design of the rocket, launch force, launch angle, environment**

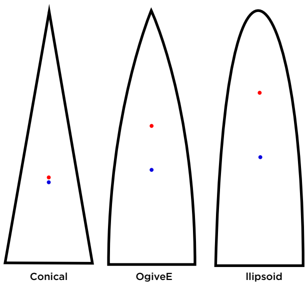
5. What variable was changed or modified in this experiment (independent)?
**Mass of the rocket**

6. What variable was measured in this experiment (dependent)?
**Distance traveled**

**Teacher Notes:**
As Newton's second law of motion states, force equals mass times acceleration (f = ma). In this experiment, students should see that as the mass of the rocket increases, the acceleration (measured as distance) decreases. The relationship between force and mass is proportional, so as mass increases, the force must also increase. The relationship between mass and acceleration is inverse. As mass increases, acceleration will decrease.

## LAB 4: EFFECT OF NOSE CONE DESIGN ON DISTANCE:

**Instructions**
In this experiment you will be evaluating the effect of the nose cone design on the distance traveled by the rocket. You should also observe the manner in which the rocket travels. For this experiment you will need to construct three rockets. Each rocket should have the same mass, length, fin design, and fin placement. The only difference should be the nose cone design.




**Part 1: Testing your rocket**
You will need to test each of three nose cones by launching at the same angle and same launch force to evaluate the effect the nose cone design has on distance traveled. Record any wobbles, spins or other irregularities within the flight of the rocket.

**Table 1: Nose Cone 1**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 2: Nose Cone 2**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: Nose Cone 3**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Part 2: Evaluation Questions**

1. How does the shape of the nose cone affect the distance traveled?
**Answers will vary — should discover that the more pointed/longer the nose, the less distance traveled.**

2. Of your three designs, which one worked the best? What advantages do you think this design had that increased the distance traveled?
**Answers will vary.**

3 a. Do you think there is anything about the design of your rocket other than the shape of the nose cone that could have affected the distance traveled?
**Answers will vary — mass of the rocket (depending on the cone), launch error, etc.**

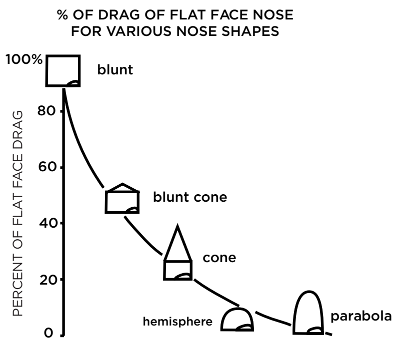
3b. If you could change the design of your rocket, what would you modify to improve the distance it traveled?
**Answers will vary.**

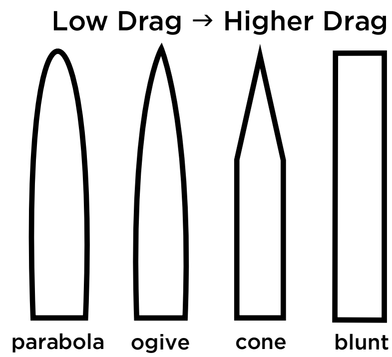
4. What variables were held constant in this experiment (control)?
**Design of the rocket (other than nose cone), launch force, launch angle, environment**

5. What variable was changed or modified in this experiment (independent)?
**Design of nose cone**

6. What variable was measured in this experiment (dependent)?
**Distance traveled**

**Teacher Notes:**
Depending on the designs of the students' nose cones, the results may vary. As the nose cone is the first thing that meets the air, it is designed to reduce the amount of drag (air resistance) on the rocket. For the paper rockets, the best design for the nose cone should be a rounded curve rather than a sharp point. You can reference students' knowledge of airplanes and rockets at this point. Anything that flies at subsonic speeds (slower than sound) has a more rounded nose cone, while vehicles that fly at supersonic speeds (faster than sound) have more pointed nose cones.




## LAB 5: EFFECT OF FIN DESIGN ON DISTANCE:

**Instructions**
In this experiment you will be evaluating the effect of fin design on the distance traveled by the rocket. You should also observe the manner in which the rocket travels. For this experiment you will need to construct three rockets. Each rocket should have the same mass, length and nose cone design. The only difference should be the shape and/or placement of the fins. Some ideas for fin designs are shown in figure 1.

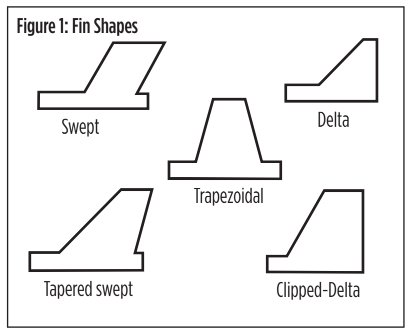


Figure 1: Fin Shapes

**Part 1: Testing your rocket**
For this challenge you will need to build three straw rockets. One should have the traditional fin design and placement on the straw (triangular, at the base). For the other two, design fins to make the rocket spin. Changes to design could include the shape, location on the straw or direction of fin placement.

**Table 1: Fin Design 1**
Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

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**Table 2: Fin Design 2**
Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

**Table 3: Fin Design 3**
Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Rod Height | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

**Part 2: Evaluation Questions**

1. How does the shape of the fins affect the flight of the rocket?
**Answers will vary — should indicate that the shape will affect the smoothness of travel (cause: wobbling, spinning, etc.).**

2. How does the placement of the fins affect the flight of the rocket?
**Answers will vary — should indicate that the farther forward the fins are placed (without changing the mass of the nose), the more the rocket will nose-dive).**

3 a. Did the distance traveled vary among the three rocket designs? If so, which design worked the best? What about the design do you think allowed it to travel farthest?
**Answers vary**

3 b. Do you think there is anything about the design of your rocket other than the fin design and placement that could have affected the distance traveled?
**Answers will vary.**

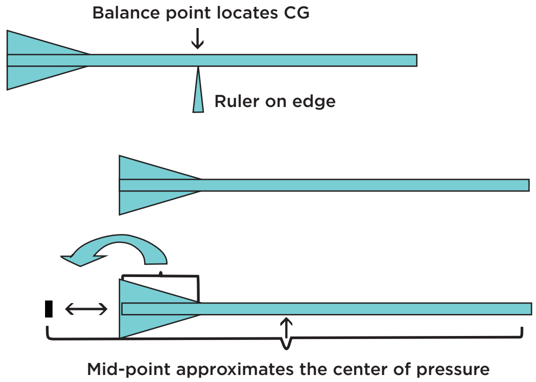
3 c. If you could change the design of your rocket, what would you modify to improve the distance it traveled?
**Answers will vary.**

4. What variables were held constant in this experiment (control)?
**Rocket length, nose cone design, launcher, launch angle, launch force**

5. What variables were changed or modified in this experiment (independent)?
**Fin design and placement**

6. What variable was measured in this experiment (dependent)?
**Distance traveled**

**Teacher Notes:**
Like many of the experiments in this lesson, there is never just one factor that determines the outcome of the experiment. However, for students to understand the principle of Newton's laws of motion, we are simplifying.

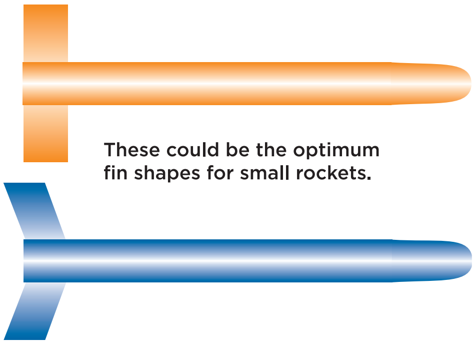



The fins of the rocket are designed to provide stability and control — or keep the rocket pointed in the right direction without wobbling. The goal is to increase the amount of drag on the tail to keep the point of the rocket flying forward. Think of an arrow. Arrows have feathers at the rear to keep the body going forward. To understand the best placement for fins, it is important to understand two concepts: center of gravity and center of pressure. The center of gravity is the point at which all the mass of an object can be thought to be concentrated (or balanced). Think of balancing a ruler on the side of your finger. The center of gravity would be the point directly above your finger while the ruler is balanced. The center of gravity can be moved closer to the nose cone of the rocket by adding the same mass near the nose cone. This will increase the overall stability of the rocket.

The center of pressure is the single point at which all the aerodynamic forces are concentrated. To find the approximate position for center of pressure, draw an outline of the rocket on a piece of paper. The center of the area of the outline shape is approximately the center of pressure.

If the center of pressure is behind the center of gravity, anytime the rocket starts to go sideways, the tail drags behind and keeps the nose pointed ahead. If both the center of gravity and center of pressure are at the same place (fins in the middle of the rocket) then the rocket tumbles because it doesn't know which end is the front and which is the back. If the center of pressure is ahead of the center of gravity (fins on the nose), the rocket will try to fly backward.

Which design is the best shape for the fin of the straw rocket? Turns out that the rectangle or parallelogram shape produces the best results because it reduces the amount of air turbulence around the rocket.



## LAB 6: MEASURING VELOCITY:

**Instructions**

In this experiment you will be evaluating the effect of launch force on the velocity of the rocket. You will need to construct one rocket that will be used for all three tests.

**Part 1: Testing Your Rocket**

After recording the mass of your rocket, you will launch your rocket three times at a 30-degree angle with a launch force as piston position 2 and, using a stopwatch, time the flight. Repeat for piston positions 3 and 5.

**Rocket Mass:** ______________________________

**Table 1: Piston Position 2**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 2 | | |
| 2 | 30° | 2 | | |
| 3 | 30° | 2 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Table 2: Piston Position 3**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 3 | | |
| 2 | 30° | 3 | | |
| 3 | 30° | 3 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Table 3: Piston Position 5**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 5 | | |
| 2 | 30° | 5 | | |
| 3 | 30° | 5 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and velocity. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation Questions**

1. What effect did the increase of pressure (force) have on the velocity of the rocket?

**The greater force applied to the rocket, the greater the velocity.**

2. Given your calculation for velocity, calculate the acceleration of the rocket. Then weigh your rocket and calculate the force that was applied to the rocket.

Acceleration = velocity (m/s) / time (s)    Force (N) = mass (Kg) x acceleration (m/s/s)

Answers will vary, but an example is provided. (Calculated from experiment.)

| | | |
|---|---|---|
| **V= 7.5 m/s** | **a= v / t** | **f= ma** |
| | **a= 7.5 m/s / 2** | **f= (.050k) (3.25m/s/s)** |
| | **a = 3.25 m/s/s** | **f = .165 N** |

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3. What variable was held constant in this experiment (control)?
**Mass and design of the rocket, launcher, launch angle**

4. What variable was changed or modified in this experiment (independent)?
**Launch force**

5. What variable(s) was measured in this experiment (dependent)?
**Distance traveled and time**

**Teacher Notes:**
Accurate timing may be difficult since the rockets don't travel far. If necessary, you can observe the rockets' speed qualitatively. The low launch angle results in additional friction as the rocket lies on the tube rather than standing on its tail. As a result, the rocket may not launch well at lower pressures (force). You can adjust the pressure accordingly to improve the results for the class. Be sure to keep the pressure consistent for each trail.

While this task focuses on velocity, it's not completely accurate, as the velocity is constantly changing because of the air drag and gravitational acceleration on the rocket. Moreover, the direction of velocity changes along the flight path. However, by keeping the launch angle low and using the average horizontal velocity, you can produce results that can lead into the discussion on the relationship between time, speed and distance.

Newton's second law states that the force is proportional to the acceleration for a fixed mass (F = m x a). In this experiment students used the same rocket so the mass didn't change. When the force is doubled, the acceleration doubles. Twice the acceleration means twice the velocity (V = a x t). When students do calculations, they may see that doubling the force results in less than double the velocity. This is because of the air drag, as it is higher at higher velocities. In fact, air drag increases as the square of velocity, so a rocket flying twice as fast will experience four times as much drag.

**Explain**
One of the most basic scientific concepts is the interaction between forces and matter. Forces are observed around us in our everyday lives, from the gravity keeping us on the ground to the wind blowing through the trees. **Forces** are interactions that cause the motion of an object to change. Only five forces are known to science. The first three — gravitational, electrical and magnetic — are the most easily observed. The second two — nuclear and weak interaction forces — occur within the nucleus of an atom and are therefore not observable to most people.

With the straw rocket, several forces are at work at any given time. When the rocket is on the launcher, gravity, or weight, is equal to the force the Earth or launchpad is exerting on it, creating inertia. **Inertia** is the tendency of a body to resist a change in its motion. When the air from the launcher enters the straw, it creates an unbalanced force, causing the rocket to take off. As the rocket moves through the air, four forces are at work: **weight**, or gravity; **thrust**, which is the force propelling it upward; **lift**, which is the perpendicular force causing the rocket to spin; and **drag**, or the friction between the air and the rocket. The interaction of these forces combined with the force of acceleration and the mass of the rocket will determine how far the rocket will travel.

While having a basic understanding of forces is important for your science grade, it is also important for your safety. Where can we see Newton's laws in everyday life? Perhaps you've ridden in a car before. Have you ever wondered why there are seat belts in your car? Cars haven't always had them! Think about Newton's first law. When the car stops, does everything else in the car stop too? No, they resist any change to their motion until something stops them. Hopefully, this is a seat belt. If not, it could be the steering wheel or windshield.

Newton's second law also applies, as the greater mass an object has the longer it takes to accelerate. It also takes the same object longer to decelerate or stop. Understanding this is critical when it comes to sharing the road with large semitrucks that are carrying heavy loads. While a car may take only a few hundred feet to stop, the semi will require significantly more distance, especially if it is loaded. So if a car stops suddenly in front of a semi, the truck is going to take longer to stop, potentially causing an accident. Remember that trucks carry cargo. Does the cargo stop because the truck stops? No, it will continue forward until it slams into the front of the trailer, propelling the trailer and thus the truck farther ahead into whatever is in front of it. Now imagine that load in the trailer was live animals such as horses or cattle.

The same can be said for rural roads and large agricultural implements. While the tractor may be moving slowly, the car that is approaching from the rear is traveling fast. Most people have trouble estimating how slow a vehicle is moving when they are traveling at high speeds. This causes many drivers to misjudge the distance between the tractor and themselves, leading to serious accidents.

**Evaluate**

1. Explain how the straw rockets demonstrated Newton's three laws of motion.

    **Newton's first law of motion is demonstrated by the inertia of the rocket sitting on the launch tube. Without an external force to act upon it, it will remain on the tube. Newton's second and third laws can be seen during the launch. As the rocket sits on the launch tube, the pressure of the tube and the rocket are equal but opposite. It isn't until there is an imbalance of pressures be tween the air inside the tube and the rocket that it is propelled forward. As the mass of the rocket increases, the acceleration decreases (distance traveled).**

2. How do the rockets demonstrate potential and kinetic energy?

    **The straw rockets also represent potential and kinetic energy. As the rocket sits on the launcher and the plunger is pulled up, it exhibits potential energy. As the plunger is released, it condenses the air in the tube, creating force that propels the rocket; this is kinetic energy.**

3. Name an example from your daily life that demonstrates one or more of Newton's laws.

    **Answers will vary.**

STUDENT GUIDE

# FORCES AT WORK: NEWTON'S LAWS OF MOTION WITH STRAW ROCKETS

## MATERIALS PER GROUP:

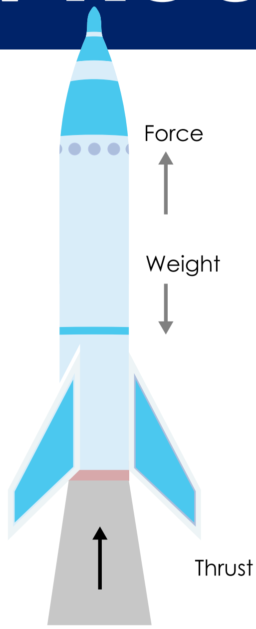
The materials for each activity will vary. See each lab for more specific information.

For all rockets, each student or student team will require:

- Straw(s)
- Paper for fins
- Paper for nose cone
- Masking or scotch tape
- Rocket launcher

## SAFETY PRECAUTIONS:

- Use caution when using scissors.
- Wear safety glasses when launching rockets.
- Be sure no one is in the path of the rocket during launch.




A body in rest or in motion will remain in its position with a constant velocity unless acted upon by a force.

## LESSON OBJECTIVES:

Students will be able to:

1. Design and construct a rocket to travel the farthest distance.
2. Evaluate the effectiveness of design to meet goal.
3. Explain how Newton's laws of motion apply to real world scenarios.

## ESSENTIAL QUESTION:

What forces exist around us?

## TOPICAL ESSENTIAL QUESTION:

How can Newton's laws of motion be applied to everyday life?

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## KEY VOCABULARY:

| | | |
|---|---|---|
| Force | Drag | Acceleration |
| Thrust | Potential Energy | Weight |
| Kinetic Energy | Mass | |
| Inertia | Lift | |

## ENGAGE:

1. How does the first demonstration show Newton's first law of motion?

2. Explain how Newton's third law of motion is shown in the second demonstration.

3. What happens in the third demonstration when mass is added to one of the carts? How does this demonstrate Newton's second law of motion?

4. Name two examples of how Newton's laws of motion can be seen in the world around you every day.

## EXPLORE:

Straw rockets are a fun method of seeing Newton's laws of motion in action. Follow the directions for the labs as indicated by your teacher. Pay close attention to the directions of each lab.

## LAB 1: EFFECT OF LAUNCH ANGLE ON DISTANCE:

**Instructions**
In this lab you will be evaluating the effect of the angle of launch on the distance traveled by your rocket. You will need to construct one rocket to be used for all three tests. Be sure your rocket includes a nose cone and fins.

**Part 1: Testing your rocket**
You will launch your rocket at three different angles while maintaining the same launch force to determine the best angle for distance. Conduct three launches and average the distance to get your results.

**Table 1: 20 ° Angle Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 20° | 4 | |
| 2 | 20° | 4 | |
| 3 | 20° | 4 | |
| Average | | | |

**Table 2: 45 ° Launch Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: 70 ° Launch Launch**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 70° | 4 | |
| 2 | 70° | 4 | |
| 3 | 70° | 4 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch angle and distance traveled by using your averages from each angle. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation Questions**

1. How does changing the angle influence distance traveled?

2. Which was the best angle of launch?

3. What forces were at work on your rocket during this experiment?

4. Based on the distances traveled and the launch angle, draw a diagram to show what you think the trajectory or flight path looked like for each angle.

5. If you could change the design of your rocket, what would you modify to improve the distance it traveled?

6. What variables were held constant in this experiment (control)?

7. What variable was changed or modified in this experiment (independent)?

8. What variable was measured in this experiment (dependent)?

## LAB 2: EFFECT OF LAUNCH FORCE ON DISTANCE:

**Instructions**

In this experiment, you will be evaluating the effect of launch force on the distance traveled by your rocket. You will use one rocket to conduct all three tests.

**Part 1: Testing your rocket**

You will launch your rocket at the same angle for each test while changing the launch force to determine the best launch force for distance. Conduct three launches and average the distance to get your results.

**Table 1: Piston Position 2**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 2 | |
| 2 | 45° | 2 | |
| 3 | 45° | 2 | |
| Average | | | |

**Table 2: Piston Position 3**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 3 | |
| 2 | 45° | 3 | |
| 3 | 45° | 3 | |
| Average | | | |

**Table 3: Piston Position 5**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 5 | |
| 2 | 45° | 5 | |
| 3 | 45° | 5 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and distance traveled using the averages. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation Questions**

1. Draw a model of the launcher to describe when and where potential energy and kinetic energy occur in the system.

2. In this experiment, how were different levels of potential and kinetic energy created?

3. How much additional distance does each increase in force produce?

4. What is the relationship between additional launch force and distance traveled?

5. What forces are acting on your rocket?

6. If you could change the design of your rocket, what would you modify to improve the distance it traveled?

7. What variables were held constant in this experiment (control)?

8. What variable was changed or modified in this experiment (independent)?

9. What variable was measured in this experiment (dependent)?

## LAB 3: EFFECT OF MASS ON DISTANCE:

**Instructions**

In this experiment you will be evaluating the effect of the mass of the rocket on distanced travelled by the rocket and, by observation, the acceleration of the rocket. For this experiment you will need to construct one rocket that you will be able add mass to by adding additional modeling clay to your nose cone.

**Part 1: Test your rocket.**

You will launch your rocket at the same angle and same launch force three times. After each launch, add modeling clay to add mass to the rocket. Record the mass before each flight.

**Table 1: Mass:** ____________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 2: Mass:** ____________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: Mass:** ____________________________________

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and distance traveled using the averages. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation questions**

1. How does the mass of the rocket affect the distance traveled?

2. What forces are acting on your rocket?

3 a. Do you think there is anything about the design of your rocket other than the mass that could have affected the distance traveled?

3 b. If you could change the design of your rocket, what would you modify to improve the distance it traveled?

4. What variables were held constant in this experiment (control)?

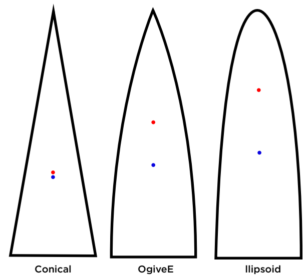
5. What variable was changed or modified in this experiment (independent)?

6. What variable was measured in this experiment (dependent)?

## LAB 4: EFFECT OF NOSE CONE DESIGN ON DISTANCE:

**Instructions**

In this experiment you will be evaluating the effect of the nose cone design on the distance traveled by the rocket. You should also observe the manner in which the rocket travels. For this experiment you will need to construct three rockets. Each rocket should have the same mass, length, fin design, and fin placement. The only difference should be the nose cone design.




**Part 1: Testing your rocket**

You will need to test each of three nose cones by launching at the same angle and same launch force to evaluate the effect the nose cone design has on distance traveled. Record any wobbles, spins or other irregularities within the flight of the rocket.

**Table 1: Nose Cone 1**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 2: Nose Cone 2**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Table 3: Nose Cone 3**

| Trial | Launch Angle | Launch Force as Piston Position | Distance |
|---|---|---|---|
| 1 | 45° | 4 | |
| 2 | 45° | 4 | |
| 3 | 45° | 4 | |
| Average | | | |

**Part 2: Evaluation Questions**

1. How does the shape of the nose cone affect the distance traveled?

2. Of your three designs, which one worked the best? What advantages do you think this design had that increased the distance traveled?

3 a. Do you think there is anything about the design of your rocket other than the shape of the nose cone that could have affected the distance traveled?

3 b. If you could change the design of your rocket, what would you modify to improve the distance it traveled?

4. What variables were held constant in this experiment (control)?

5. What variable was changed or modified in this experiment (independent)?

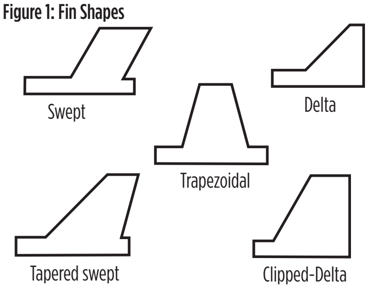
6. What variable was measured in this experiment (dependent)?

## LAB 5: EFFECT OF FIN DESIGN ON DISTANCE:

**Instructions**

In this experiment you will be evaluating the effect of fin design on the distance traveled by the rocket. You should also observe the manner in which the rocket travels. For this experiment you will need to construct three rockets. Each rocket should have the same mass, length and nose cone design. The only difference should be the shape and/or placement of the fins. Some ideas for fin designs are shown in figure 1.

Figure 1: Fin Shapes




**Part 1: Testing your rocket**

For this challenge you will need to build three straw rockets. One should have the traditional fin design and placement on the straw (triangular, at the base). For the other two, design fins to make the rocket spin. Changes to design could include the shape, location on the straw or direction of fin placement.

**Table 1: Fin Design 1**

Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

**Table 2: Fin Design 2**

Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

**Table 3: Fin Design 3**

Description/picture of fin design and placement:

| Trial | Launch Angle | Launch Force as Rod Height | Distance | Notes about Flight |
|---|---|---|---|---|
| 1 | 45° | 4 | | |
| 2 | 45° | 4 | | |
| 3 | 45° | 4 | | |
| Average | | | | |

**Part 2: Evaluation Questions**

1. How does the shape of the fins affect the flight of the rocket?

2. How does the placement of the fins affect the flight of the rocket?

3 a. Did the distance traveled vary among the three rocket designs? If so, which design worked the best? What about the design do you think allowed it to travel farthest?

3 b. Do you think there is anything about the design of your rocket other than the fin design and placement that could have affected the distance traveled?

3 c. If you could change the design of your rocket, what would you modify to improve the distance it traveled?

4. What variables were held constant in this experiment (control)?

5. What variables were changed or modified in this experiment (independent)?

6. What variable was measured in this experiment (dependent)?

## LAB 6: MEASURING VELOCITY:

**Instructions**

In this experiment you will be evaluating the effect of launch force on the velocity of the rocket. You will need to construct one rocket that will be used for all three tests.

**Part 1: Testing Your Rocket**

After recording the mass of your rocket, you will launch your rocket three times at a 30-degree angle with a launch force as piston position 2 and, using a stopwatch, time the flight. Repeat for piston positions 3 and 5.

**Rocket Mass:** ______________________________

**Table 1: Piston Position 2**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 2 | | |
| 2 | 30° | 2 | | |
| 3 | 30° | 2 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Table 2: Piston Position 3**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 3 | | |
| 2 | 30° | 3 | | |
| 3 | 30° | 3 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Table 3: Piston Position 5**

| Trial | Launch Angle | Launch Force as Piston Position | Distance | Time |
|---|---|---|---|---|
| 1 | 30° | 5 | | |
| 2 | 30° | 5 | | |
| 3 | 30° | 5 | | |
| Average | | | | |

Average velocity=distance/time: ______________________________

**Part 2: Graph your data.**

Create a line graph to show the relationship between launch force and velocity. Be sure to label your axes and provide units where needed.

**Part 3: Evaluation Questions**

1. What effect did the increase of pressure (force) have on the velocity of the rocket?

2. Given your calculation for velocity, calculate the acceleration of the rocket. Then weigh your rocket and calculate the force that was applied to the rocket.

3. What variable was held constant in this experiment (control)?

4. What variable was changed or modified in this experiment (independent)?

5. What variable(s) was measured in this experiment (dependent)?

**Explain**

One of the most basic scientific concepts is the interaction between forces and matter. Forces are observed around us in our everyday lives, from the gravity keeping us on the ground to the wind blowing through the trees. **Forces** are interactions that cause the motion of an object to change. Only five forces are known to science. The first three — gravitational, electrical and magnetic — are the most easily observed. The second two — nuclear and weak interaction forces — occur within the nucleus of an atom and are therefore not observable to most people.

With the straw rocket, several forces are at work at any given time. When the rocket is on the launcher, gravity, or weight, is equal to the force the Earth or launchpad is exerting on it, creating inertia. **Inertia** is the tendency of a body to resist a change in its motion. When the air from the launcher enters the straw, it creates an unbalanced force, causing the rocket to take off. As the rocket moves through the air, four forces are at work: **weight**, or gravity; **thrust**, which is the force propelling it upward; **lift**, which is the perpendicular force causing the rocket to spin; and **drag**, or the friction between the air and the rocket. The interaction of these forces combined with the force of acceleration and the mass of the rocket will determine how far the rocket will travel.

While having a basic understanding of forces is important for your science grade, it is also important for your safety. Where can we see Newton's laws in everyday life? Perhaps you've ridden in a car before. Have you ever wondered why there are seat belts in your car? Cars haven't always had them! Think about Newton's first law. When the car stops, does everything else in the car stop too? No, they resist any change to their motion until something stops them. Hopefully, this is a seat belt. If not, it could be the steering wheel or windshield.

Newton's second law also applies, as the greater mass an object has the longer it takes to accelerate. It also takes the same object longer to decelerate or stop. Understanding this is critical when it comes to sharing the road with large semitrucks that are carrying heavy loads. While a car may take only a few hundred feet to stop, the semi will require significantly more distance, especially if it is loaded. So if a car stops suddenly in front of a semi, the truck is going to take longer to stop, potentially causing an accident. Remember that trucks carry cargo. Does the cargo stop because the truck stops? No, it will continue forward until it slams into the front of the trailer, propelling the trailer and thus the truck farther ahead into whatever is in front of it. Now imagine that load in the trailer was live animals such as horses or cattle.

The same can be said for rural roads and large agricultural implements. While the tractor may be moving slowly, the car that is approaching from the rear is traveling fast. Most people have trouble estimating how slow a vehicle is moving when they are traveling at high speeds. This causes many drivers to misjudge the distance between the tractor and themselves, leading to serious accidents.

**Evaluate**

1. Explain how the straw rockets demonstrated Newton's three laws of motion.

2. How do the rockets demonstrate potential and kinetic energy?

3. Name an example from your daily life that demonstrates one or more of Newton's laws.