I Love Science Activity

Program III

December 9, 2008

ACTIVITY VOCABULARY

Aerospace, velocity, speed, force, gravity and acceleration

1. Force

2. Gravity

3. Speed

4. Velocity

5. Acceleration

6. Balanced forces

7. Unbalanced forces

ACTIVITY VOCABULARY KEY

Aerospace, velocity, speed, force, gravity and acceleration

1. Force — a push or a pull that caused changes in motion

8. Gravity — force of attraction between an object and Earth

9. Speed — distance an object travels in a certain amount of time

10. Velocity — measure of an object's speed in a particular Direction

11. Acceleration — rate at which velocity changes

12. Balanced forces — forces that act on an object but cancel each other

13. Unbalanced forces — forces that act on an object and cause a change in motion

LESSON PLAN

⇒For this special ONE DAY, ALL 5TH GRADE SCIENCE ILS activity, each class should be divided into five launch teams. Have the students select a space name for their team (Saturn, Atlas, etc.), and wear a badge or sign with the team name (the teacher's name on the bottom may be a good idea as well). This will facilitate keeping the classes together by teacher, so that each group has an opportunity to "launch" their selected rocket design.

⇒For each team, one student should be designated for each of these duties:

a. Launch controller
b. Data recorder
c. Field rocket spotter (immediately marks the point at which the teams rocket hits the ground until the field measurer arrives with the tape end and data recorder documents)
d. Launcher station tape measure holder (hold the tape measure at the launching table)
e. Field distance measurer and rocket retriever (take the tape end out on the field to point where the rocket drops; holds the tape end as it is rewound; and, returns the rocket for the next shoot)
f. Timer (record the time from rocket launch to landing) recommend class teacher in this role.

⇒REMEMBER: The expectation is that this ILS activity will be held outside, with the launchers stationed on tables across one end of the field. The classes' teams will be lined up behind their assigned launchers—each of the class teams will rotate, using their assigned launcher, and have their opportunity to launch their rocket at least 3 time and record data—team by team.

⇒Each team will need to have a writing surface (clip board), a pencil and the exercise data collection sheet included with the lesson plan. After the

Data Recorder completes the information during the launching part of the activity, copies can be made for each team member for classroom exercises.

<u>The launching exercise will be explained at the end of the lesson plan</u>**

⇒Ahead of the ILS class, be sure:

a. The students complete the vocabulary sheets
b. Within their assigned teams, each member constructs at least two (2) straw rockets of the "fin and nose cone design" selected by the group—then *they* will decide which rocket will be THE ONE launched on the ILS Activity Day (12/9). This rocket should be placed in its own separate container (a plastic cup, for instance)—and have a back-up version as well!
c. The students, in selecting the team rocket design, should also discuss and form a hypothesis—i.e.: "If the fins are (this shape) and the nose cone is (tape or clay), then the rocket will fly (farther or faster) than the other team's rocket…"
d. The teams are thoroughly familiar with the order of the launching activity—especially their assigned duties within their teams.

⇒Please note the following attachments:

a. Straw rocket construction packet
    - ♦Rocket construction materials
        - •Special neon plastic straws with flexible drinking end (this will be cut off, leaving a straight straw portion)
        - •1 ½ inch masking tape
        - •1 stick of modeling clay
    - ♦ Rocket design instruction sheet (for fins and nose cone)
b. Basic procedure for straw rocket construction
c. Rocket Launch Data Sheet (for Data Recorder to complete during launching exercise)
d. 5th Grade Science Teacher lesson background information
e. I Love Science Straw Rocket Launching Activity Exercise and Team Information sheet. **

⇒The volunteers will be using, explaining and (assistants) demonstrating the vocabulary all during class to promote familiarity of the terms with actions observed.

<u>Launching Exercise</u>
Each team will launch its rocket 3-5 times at various force settings using the straw rocket launcher. Teams will average the measurements to get their result.

Place the rocket launcher on a stable platform at a convenient working height for the students.

For each set of launches:

1. The launcher station tape measure holder places the rocket on the launch tube.

2. The launch controller lifts and releases the launcher's piston. To launch a rocket, grip the upright cylinder around the middle below the rubber band and raise the piston by holding on to the cap at the top. Raise the piston to the desired position and release to launch. The controller calls "launch" as they release the piston to launch the rocket to cue the timer (teacher) to start the stopwatch.

3. The timer starts the stopwatch when the controller calls "launch" and stops the stopwatch when the field rocket spotter calls "mark" as the rocket lands.

4. The field rocket spotter calls "mark" as the rocker lands and marks the rocket's landing point.

5. The field distance measurer/rocket retriever measures the distance the rocket traveled from the launcher, returns the rocket to the launcher and passes the distance information to the recorder.

6. The data recorder writes down the results after each launch.

SAFETY NOTE – the rockets are very light and blunt. However, they should not be launched directly at a person. Make sure all students are out of the line of flight before launching.

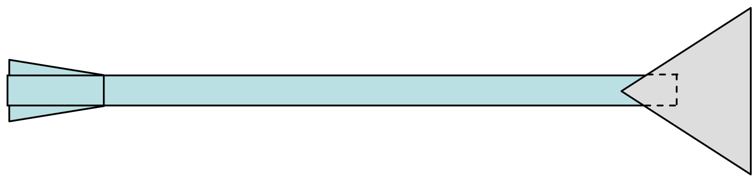
7. Launch each rocket three-five times at five units of force (raise piston 2 ½”) and a 45 degree angle (if indoors use 20-30 degrees to avoid bouncing rockets off of the ceiling). Record the information in the data table and note how the rocket moves through the air – its trajectory.

8. Repeat the experiment using the same angle for ten units (raise piston 5”) and 15 units (7 ½”) of force and record the results.

9. Have the students compute the average distance and speed for each set of launches.

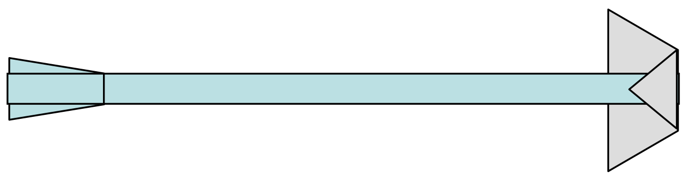
Straw Rocket: nose

1.



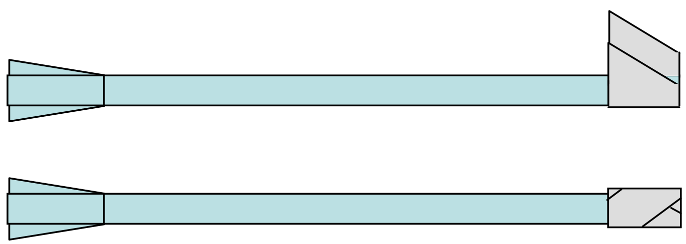
Place triangular piece of tape on nose.

2.



Pinch straw shut and fold tape over the nose.

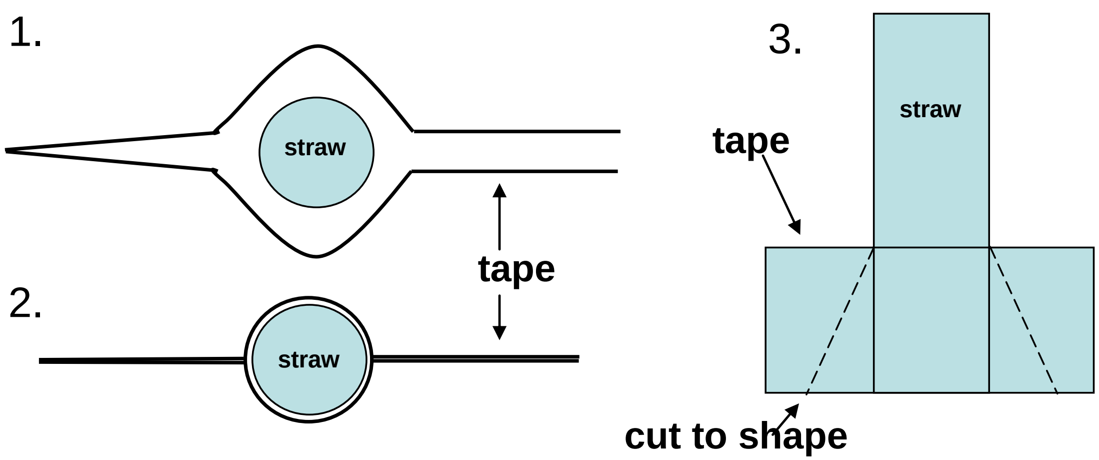
3.



Wrap remaining tape around straw to seal.

Straw Rocket: fins

Fins: wrap tape around bottom of straw as shown (1).
Pinch the two “fins” flat (2).
Trim the tape to desired shape (3).



Basic Procedure for Straw Rocket Construction

1. Provide each student with one straw (have a spare ready). Cut off the "bendy" section with scissors if using flexible straws. Discard straws that are pinched or crooked.

2. Have the students plug one end of their straw to make the rocket.

> This can be done using modeling clay. Take a piece of clay just bigger than a pencil eraser and roll it in a ball. Push one end of the straw through the clay, forming a plug inside that end. The plug will end up about ¼" to ½" long.
>
> Tape can be used instead of clay. Cut a triangular piece of tape about 1-1/2" on a side. Place the piece of tape on the straw with the point of the triangle about ¾" from the end of the straw (see diagram). Pinch the end of the straw shut and fold the tape over the pinch to secure it. Roll the remaining "wings" of tape around the straw (one at a time) to secure the end.

3. Have the student add fins of their own design to the straw rocket. To form the basis for the fins, cut a 3" long piece of masking tape. Carefully pinch the middle of the tape and stick about 3/4" of the tape together – keeping the free ends apart. Lay the straw in the groove formed by the tape between the two free ends and then bring the free ends together. Carefully pinch the tape together to secure it around the straw. Use a scissors to cut the fins to shape.

4. Measure the rocket (weight, length) and record the information in the data table provided.

ROCKETS AWAY DATA SHEET.

TEAM NAME:______________________________ Rocket: Weight _____________
Length _____________

Use 45 degree launch angle outdoors, 20-30 degrees for indoor launches.

Trial Number	Launch Angle	Launch Force	Distance	Time	Average Velocity
1		5			
2		5			
3		5			
Average					

Trial Number	Launch Angle	Launch Force	Distance	Time	Average Velocity
1		10			
2		10			
3		10			
Average					

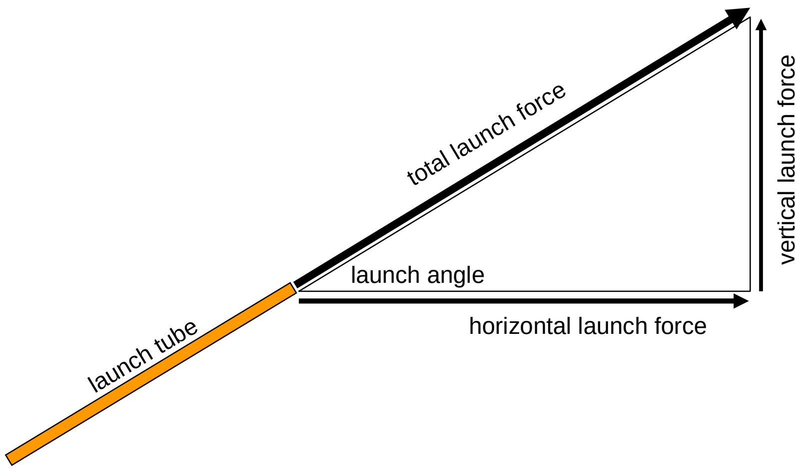
Trial Number	Launch Angle	Launch Force	Distance	Time	Average Velocity
1		15			
2		15			
3		15			
Average					

Average velocity = distance / time ____________________________

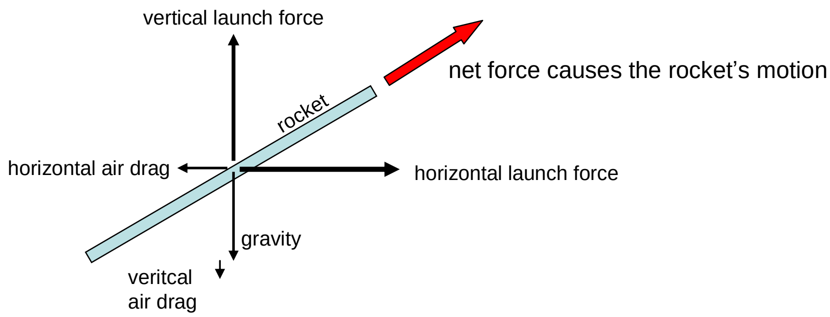
SCIENCE BACKGROUND

Forces on the rocket: Launch force, gravity, air drag.

Launch force comes from the tension in the rubber band driving the launcher's piston. For analysis, this force needs to be separated into two components – vertical and horizontal. Decomposing the force is straightforward trigonometry.



Unbalanced forces on the rocket at launch



For a given launch angle, the vertical component is the sine of the launch angle times the total launch force; the horizontal component is given by the cosine of the launch angle times the total launch force.

Gravity acts on the rocket's mass and constantly pulls the rocket downward toward the center of the earth. The vertical component of the rocket's initial launch force opposes gravity. The rocket initially moves upward because the vertical launch force is greater that the force of gravity on the rocket. Once the rocket leaves the launch tube, gravity acts unopposed to slow the rocket's upward travel. Eventually, gravity stops the rocket's upward motion and starts to accelerate the rocket downward, bringing the rocket back to the ground.

Air drag is caused by the rocket pushing aside the air molecules as it flies. Air drag directly opposes the rocket's motion and is only effective when the rocket is moving. Air drag is directly proportional to the square of the rocket's velocity and therefore rises quickly as the rocket accelerates – and drops just as quickly as the rocket slows. The drag force acts directly against the rocket's direction of motion and so acts against both the rocket's vertical and horizontal launch force. Since the rocket's vertical velocity quickly slows under the influence of gravity, we will neglect that component of drag and focus on the horizontal component of air drag – acting against the horizontal component of the rocket's initial launch force. Once the rocket leaves the launch tube, air drag acts unopposed to slow the rocket's horizontal travel. Eventually, air drag would slow the rocket to a stop – practically, the rocket will hit the ground long before this point except for extremely high launch angles.

Before launching, the rocket is at rest and the forces are balanced. The launch tube supports the rocket, balancing the gravitational force. There is no launch force from the piston yet, and no air drag since the rocket is not moving through the air.

Releasing the launcher's piston unbalances the forces and sets the rocket in motion.

The basic relation:

$F = m \times a$ [Newtons = kilograms x meters/second^2]

reduces to:

$a = F / m$ to determine acceleration.

This tells us that for a given force (F) a rocket with less mass (m) will have a higher acceleration (a) or that using more force to push the same mass will also yield higher acceleration. Higher acceleration over the same amount of time (t) will result in a higher velocity (v).

Velocity is described by:

$v = a \times t$

which combined with the previous equation yields

$v = (F / m) \times t = (F \times t) / m$

This tells us that twice the force will give twice the initial launch velocity for one rocket. It also tells us that for two rockets, the first one having half the mass of the second, the same force will push the lighter rocket to twice the initial launch velocity.

The fastest student rockets will likely be the lightest.

Once launched, the rocket's motion is determined by the drag and gravitational forces.

Air drag is caused by the rocket pushing aside the air molecules at the rocket moves through the air. Since it is a collision force, it is strong when the rocket is moving rapidly and very weak when the rocket is moving slowly (just a car collision is catastrophic at 40 mph but an annoyance at 2 mph). Air drag is a complex function, related to the frontal area and shape of the rocket as it meets the airflow and the characteristics of the air (density and viscosity). For this lesson, the important points are: air drag opposes the direction of motion and air drag is proportional to the square of the rocket's velocity. This means doubling a rocket's speed increases its air drag four times.

Air drag does affect how fast the rocket falls, but this is obvious only for rockets with very different drag characteristics.

The gravitational force on the rocket is determined by the rocket's mass, the mass of the earth, and the rocket's distance from the center of the earth. Since none of these is changing significantly during the experiment, the gravitational force on a rocket is essentially constant. This constant force brings the rocket's vertical rise to a stop and then accelerates it back down to the ground.

Gravitational force (F) is expressed as:

$$F = (G \times m_r \times m_e) / r^2$$

where G is a constant, m_r is the mass of the rocket, m_e is the mass of the earth, and r is the distance between the rocket and the center of the earth.

A heavier (more massive) rocket will feel more gravitational force than a light one – BUT – the acceleration imparted by gravity will be the same for both. A more massive rocket experiences more gravitational force but the more massive rocket also has more inertia that resists any change in motion. This means rockets (or any masses) of unequal weight will have the same vertical velocity as they drop.

As seen above, acceleration of a rocket is:

$$a = F / m_r$$

combining with the gravitational force equation yields:

$$a = (G \times m_r \times m_e) / (r^2 \times m_r)$$ and canceling terms yields:

$$a = (G \times m_e) / r^2$$

showing the acceleration of gravity depends only on the mass of the earth and the distance from the rocket to the center of the earth – all constant for this experiment. Since the acceleration is the same, the velocity will be the same as shown above.

A projectile follows a parabolic trajectory after it is launched, moving under the influence of gravity alone. Derivation of the equation of motion and the exact effect of air drag in modifying the rocket's trajectory is beyond the scope of this lesson. Discussing these factors in general terms should be sufficient.

Some elementary vector analysis can tell us how far a rocket will travel for a given initial launch force. We are interested in how far the rocket travels downrange – horizontally. Distance traveled is given by:

d(distance) = v(velocity) x t(time).

So, how far the rocket travels is determined by how fast it is going (horizontal velocity) and how long it stays in the air (since it stops on landing). We calculated velocities above.

v = a x t Solving for time gives:

t = v / a so if we start with the initial vertical velocity divided by the acceleration of gravity we get the time for the rocket to come to a stop at the top of its trajectory (20m/s velocity decelerating at $10m/s^2$ will come to a stop in two seconds).

The total time of flight is:

flight time = 2 x v_v(vertical velocity) / g(acceleration of gravity)

The factor of two is needed to account for both the rocket's rise and fall. The rocket's rise is first decelerated by gravity until it reaches its highest point and then the rocket is accelerated back down by the same gravitational force. The rocket spends the same amount of time going up as coming down since the gravitational force and acceleration of gravity are constant.

More force yields more acceleration and a higher initial velocity. A higher velocity makes both the vertical and horizontal components of velocity proportionately faster. Therefore, doubling the launch force will double the rocket's horizontal velocity. Doubling the launch force will also double the vertical velocity, thereby doubling the rocket's flight time. So, we end up finding that doubling the force has doubled both the horizontal velocity and the time the rocket is in the air and moving. In the distance equation we now have:

new d(distance) = 2v(velocity) x 2t(time).

This means that twice the force will send the rocket four times as far. If this seems counterintuitive, remember that a projectile is still moving when it lands – both horizontally and vertically. This energy is wasted. Doubling the velocity takes the rocket twice as far in a given time, but by keeping the rocket in the air longer we give the rocket even more time to continue its (faster) horizontal motion. That's where the additional benefit comes from – more time in flight.

The result is best seen if you demonstrate using your straightest straw to make a very light rocket and launching the rocket with minimum force. Straight, light straws will minimize friction losses on the launch tube. Minimum force will keep the rockets slow and minimize air drag. Launching at 2 force units (raise piston 1") and 4 force units should show a significant result, with the stronger force sending the rocket significantly more than twice as far as the lighter force.

Simplifying greatly, the distance the rocket travels (ignoring air resistance) should be proportional to the square of the rocket's launch velocity. Since velocity is proportional to the force, twice the force will ideally send the rocket four times as far if there is no air resistance. However, you will likely not get this result as the air drag – opposing the rocket's motion – also increases as the square of the velocity. Stick a qualitative explanation above.

SCRIPT IDEA

Basic concepts and rocket construction.

What we will talk about today—forces, motion, gravity, and acceleration.

Review the vocabulary with students. Words that might come into the discussion will be distance, speed, velocity, acceleration, force, gravity.

Take a straw and toss it though the air – ask the students why it doesn't go far. The straw is very light and unstable, so it is quickly stopped by air drag and tumbles.

What does air resistance mean? It is a force that resists motion through air due to the presence of air molecules in the path of the object. Air resistance is usually called drag. You can feel air drag in the force of the wind on a windy day.

Take a straw with one end plugged with modeling clay and toss it, plugged end forward – ask the students why it flew better than just a straw. This demonstrates the inertia of objects and Newton's first law. A more massive object has more inertia and thus a stronger tendency to continue moving once set in motion. It also demonstrates basic stability – see below.

Ask the students why both straws fell to the ground. The force of gravity pulls objects toward the center of the earth. To get an object to rise requires a force to oppose the force of gravity. A continuous force opposing gravity can cause an object to hover or continue upward so long as the force is exerted. An impulse (a short, non-continuous force like throwing a ball) can provide enough force to initially overcome gravity and cause an object to rise straight up, but the object will slow down and eventually begin falling back to earth after the impulse force stops.

> If the students ask how satellites stay up – the answer is that satellites are launched with enough velocity around the earth (not just straight up) so that they are in a freely falling orbit. Using a circle on the board, show that if an object moves forward as quickly as it falls it can maintain the same distance from the center of the circle. This is what a satellite in orbit does.

Have the students make their rockets.

1. Provide each student with one straw (keep a spare handy). Cut off the "bendy" section with scissors if using flexible straws. Discard straws that are pinched or crooked.

2. Have the students plug one end of their straw to make the rocket.

> This can be done using modeling clay. Take a piece of clay just bigger than a pencil eraser and roll it in a ball. Push one end of the straw through the clay, forming a plug inside that end. The plug will end up about ¼" to ½" long.

Tape can be used instead of clay. Cut a triangular piece of tape about 1-1/2" on a side. Place the piece of tape on the straw with the point of the triangle about ¾" from the end of the straw (see attached diagram). Pinch the end of the straw shut and fold the tape over the pinch to secure it. Roll the remaining "wings" of tape around the straw (one at a time) to secure the end.

3. Have the student add fins of their own design to the straw rocket. To form the basis for the fins, cut a 3" long piece of masking tape. Carefully pinch the middle of the tape and stick about 3/4" of the tape together – keeping the free ends apart. Lay the straw in the groove formed by the tape between the two free ends and then bring the free ends together. Carefully pinch the tape together to secure it around the straw. Use a scissors to cut the fins to shape.

4. Measure the rocket (weight, length) and record the information in the data table provided.

Ask selected students to explain their design. Key considerations are the weight of the rocket, its balance (nose heavy), and its stability (fins or other appendages at the back end).

Explanation of stability. Objects prefer to move around their center of mass. Weighting the nose of the rocket puts the center of mass closer to the front of the rocket so that if the rocket wobbles the tail end will do most of the wobbling. As the tail end swings out – no longer aligned with the rocket's forward motion – it sees more air drag as it gets sideways. That drag force pushes the tail back into line with the rocket's forward motion though the air. Adding fins to the tail simply increases the area the drag force has to push against if the rocket wobbles.

Divide the students into teams. Have each team decide which of their rockets will travel farthest and explain why (hypothesis).

Have each team pick its best rocket.

Proceed to the launcher.

For each set of launches:
1. The launcher station tape measure holder places the rocket on the launch tube.
2. The launch controller lifts and releases the launcher's piston. The controller calls "launch" as they release the piston to launch the rocket to cue the timer (teacher) to start the stopwatch.
3. The timer starts the stopwatch when the controller calls "launch" and stops the stopwatch when the field rocket spotter calls "mark" as the rocket lands.
4. The field rocket spotter calls "mark" as the rocker lands and marks the rocket's landing point.
5. The field distance measurer/rocket retriever measures the distance the rocket traveled from the launcher, returns the rocket to the launcher and passes the distance information to the recorder.
6. The data recorder writes down the results after each launch.

SAFETY NOTE – the rockets are very light and blunt. However, they should not be launched directly at a person. Make sure all students are out of the line of flight before launching.

1. Each team will launch its rocket 3-5 times at various force settings using the straw rocket launcher. Teams will average the measurements to get their result.

2. Place the rocket launcher on a stable platform at a convenient working height for the students.

3. To launch a rocket, grip the upright cylinder around the middle below the rubber band and raise the piston by holding on to the cap at the top. Raise the piston to the desired position and release to launch.

4. Launch each rocket three-five times at five units of force (raise piston 2 ½") and a 45 degree angle (if indoors use 20-30 degrees to avoid bouncing rockets off of the ceiling). Record the information in the data table and note how the rocket moves through the air – its trajectory.

5. Repeat the experiment using the same angle for ten units (raise piston 5") and 15 units (7 ½") of force and record the results.

6. Have the students compute the average distance and speed for each set of launches.

What happened? Have the students explain their results to the class. Try to elicit motion words such as accelerated, velocity, etc. What forces were acting on the rockets?

Questions for discussion:

What causes the rockets to move?

> Changes in motion require a **force**. The rocket's motion changes from stationary on the launch tube to flying through the air. The force is provided by a puff of air driven by the stretched rubber band. The students can feel the force in the tension of the rubber band. You can also release the launcher's piston without a rocket on the launch tube and let the students feel the air coming out of the tube. See Newton's first law above.

Why do the rockets travel in a curved path?

> Have the students draw a picture of their rocket's path. A change in the direction of the rocket's flight implies **unbalanced forces** are acting on the rocket. See Newton's first law above.
>
> The rocket's motion is controlled by four forces. Thrust from the launcher provides two of these, a vertical (upward) force and a horizontal force that accelerate the rocket up and away from the launcher. The balance of these forces depends on the launch angle - higher angles give more vertical force and less horizontal force, lower angles give less vertical and more horizontal force. Gravity pulls the mass of the rocket down. Air drag slows the rocket down, reducing its velocity.
>
> Before launching, the rocket is at rest and the forces are balanced. The launch tube supports the rocket, balancing the gravitational force. There is no launch force from the piston yet, and no air drag since the rocket is not moving through the air.

The forces are unbalanced as the rocket launches. The launch force overcomes the gravitational and drag forces to set the rocket in motion.

The launch force ends as the rockets leave the launch tube. From this point on, the rockets are affected only by gravity and air drag. The gravitational force constantly pulls the mass of the rocket downward toward the center of the earth. This force slows the rocket's upward flight and eventually stops the rocket's ascent as it reaches the highest point in its flight. Gravity continues to pull on the rocket for the remainder of the flight, causing the rocket to drop back to the ground.

Air drag also affects the rocket, but its effects are difficult to see in this experiment unless the student's rocket is extremely light. As soon as the rocket leaves the launch tube the rocket no longer experiences a thrust force. Air drag slows the velocity of the rocket, reducing both its horizontal and vertical speed. This reduces the rocket's maximum height and the total distance it travels.

What is the relationship between the force used to launch the rockets and their average speed? Have the teams graph their results.

Newton's second law tells us that the force is proportional to the acceleration for a fixed mass.

F(force) = m(mass) x a(acceleration).

Each team of students used the same rocket for the entire experiment so the mass is the same. Doubling the force doubles the rocket's acceleration. Twice the acceleration produces twice the velocity:

v(velocity) = a(acceleration) x t(time).

The rockets spend almost the same amount of time on the launch tube under acceleration, so doubling the acceleration should double the initial velocity. **More force yields more acceleration and a higher initial velocity.**

Actual results will likely show a little less than twice the average velocity for twice the force since air drag is much greater for higher velocities. Air drag increases as the square of the velocity, so a rocket flying twice as fast will experience four times as much air drag slowing it down.

What is the relationship between the force used to launch a rocket and the distance the rocket travels?

More force yields more acceleration and a higher initial velocity as seen above. This higher velocity makes both the vertical and horizontal components of velocity proportionately faster.

The rocket starts upward faster (vertical velocity vector) which means it takes longer for the constant acceleration of gravity to slow it to a stop and bring it down. Thus, the faster rocket reaches a higher altitude and has a longer hang time. Twice the initial launch

force gives twice the acceleration, yielding twice the vertical velocity, and doubling the hang time.
The horizontal velocity is simpler since it is relatively constant and only affected by air drag. Twice the initial launch force gives twice the acceleration, yielding twice the horizontal velocity.
The horizontal distance traveled by a moving object is simply the rate of movement (velocity) times the time, or:

d(distance) = v(velocity) x t(time).

So, we end up finding that doubling the force has doubled <u>both</u> the horizontal velocity and the time the rocket is in the air and moving. This means that twice the force will send the rocket four times as far.

Doubling the launch force gives us a new distance equal to 2v x 2t = 4 v x t

Simplifying greatly, the distance the rocket travels (ignoring air resistance) should be proportional to the square of the rocket's launch velocity. Since velocity is proportional to the force, **twice the force will ideally send the rocket four times as far if there is no air resistance**. However, you will likely not get this result as the air drag – opposing the rocket's motion – also increases as the square of the velocity. Stick to a qualitative explanation.

The result is best seen if you demonstrate using your straightest straw to make a very light rocket and launching with minimum force. Straight, light straws will minimize friction losses on the launch tube. Minimum force will keep the rockets slow and minimize air drag. Launching at 3 force units (raise piston 1 ½") and 6 should show the result.

Which team's rocket traveled the farthest? Why?

With the launch angle fixed, the rocket that has the fastest initial velocity, is reasonably stable, and has low drag should travel farthest for a given initial launch force.

Since the force available is the same for all teams' rockets, the only way to achieve a higher acceleration and faster velocity is with a lighter rocket. The lighter rocket accelerates more quickly and can achieve a higher initial velocity. HOWEVER, the effects of air drag come into play with the lightest rockets. A light rocket has less inertia than a heavier rocket and is more quickly slowed by air drag. The lightest rockets move through the air more like a foam ball than a lead bullet (specifically the ratio of rocket mass to frontal area, which controls drag, is low). The rocket's energy is quickly lost to drag – that drag being determined by the rockets' size and shape and proportional to the square of the velocity.

Sufficient stability is also required for maximum range. Without something to stabilize it (fins, spin, trailing stick or string) the rocket will tumble. A tumbling rocket will present much more area to the airflow and therefore have greatly increased drag.

Minimizing drag maximizes range. Drag is minimized when the frontal area and surface area of the rocket are least. Practically, this is achieved with small stabilizing fins. Angling the fins to spin the rocket may allow smaller fins to be used. This comes at a cost as the energy used to spin up the rocket, increasing its angular momentum, is extracted from the initial thrust and increases drag. Streamlining the nose cone is possible, but has little effect at the speeds achieved with the apparatus.

Which team's rocket went fastest? Why?

The arguments above apply here as well. The rocket with the fastest initial velocity for the fixed force setting will have the highest average speed – assuming reasonable stability and drag. Since the force available is the same for all teams' rockets, the only way to achieve a higher acceleration and faster velocity is with a lighter rocket. The lighter rocket accelerates more quickly and can achieve a higher initial velocity. HOWEVER, the effects of air drag come into play with the lightest rockets. A light rocket has less inertia than a heavier rocket and is more quickly slowed by air drag.
The winning rocket will balance these factors, with just enough weight to carry it the distance.