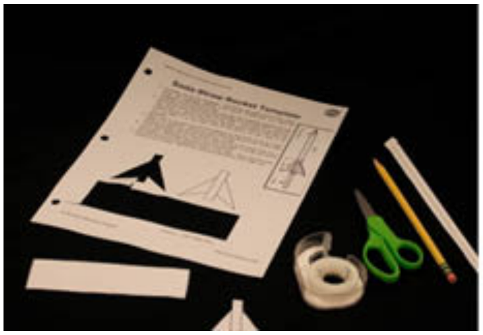
Lesson: Soda Straw Rockets

Grades: 3rd – 5th Grade **Prep Time:** ~15 Minutes **Lesson Time:** ~90 Minutes



WHAT STUDENTS DO: Test a rocket model and predict its motion.

Curiosity about what lies beyond our home planet led to the first rocket launches from Earth and to many exploration missions since. Using simple materials (soda straws and paper), students will experience the processes involved in engineering a rocket. Conducting engineering tests, students will have the opportunity to answer a research question by collecting and analyzing data related to finding out the best nose cone length and predicting the motion of their model rockets. In this collection, this lesson builds on the concept of using models encountered in Lessons 1-3, and introduces the concepts of prediction and hypothesis.

NRC FRAMEWORK / NGSS CORE & COMPONENT QUESTIONS

HOW CAN ONE EXPLAIN AND PREDICT INTERACTIONS BETWEEN OBJECTS AND WITHIN SYSTEMS OF OBJECTS?

NRC Core Question: PS2: Motion and Stability: Forces and Interactions

How can one predict an object's continued motion, changes in motion, or stability?

NRC PS2.A: Forces and Motions

What underlying forces explain the variety of interactions observed?

NRC PS2.B: Types of Interactions

HOW DO ENGINEERS SOLVE PROBLEMS?

NRC Core Question: ETS1: Engineering Design

What is energy?

NRC PS3.A: Definitions of Energy

What is a design for? What are the criteria and constraints of a successful solution?

NRC ETS1.A: Defining and Delimiting an Engineering Problem

INSTRUCTIONAL OBJECTIVES (IO)

Students will be able to

IO1: Plan and conduct an investigation into the effects of forces on the distance and path traveled of a soda straw rocket using empirical evidence to explain the impact of a net force on an object.

On behalf of NASA's Mars Exploration Program, this lesson was prepared by Arizona State University's Mars Education Program, under contract to NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology.

What is the process for developing potential design solutions?

NRC ETS1.B: Developing Possible Solutions

How can the various proposed design solutions be compared and improved?

NRC ETS1.C: Optimizing the Design Solution

1.0 Materials

Required Materials

Please supply:

- 30 Sharpened Pencils (1 per person)
- 15 Scotch Tape Rolls – 1/4" tape if possible
- 30 Individually Wrapped Drinking Straws (1 per person)
- 15 Meter Sticks or Tape Measures
- LCD projector and computer with internet access to find pictures or video of rockets on the following site: http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html.
- OR pre-construct rockets prior to class (1 per person)

Materials Provided

Please Print:

From Lesson:

(A)	Soda-Straw Rocket Template	– 1 per student
(B)	Safety Procedure	– 1 per student
(C)	Forces and Net Forces Explained	– 1 per student
(D)	Soda-Straw Rocket Initial Results	– 1 per student
(E)	Soda-Straw Rocket Engineering Design	– 1 per student
(F)	Soda-Straw Engineering Design Conclusions	– 1 per student
(G)	Soda-Straw Rocket Engineering Design Evaluation	– 1 per student

Optional Materials

From Teacher Guide:

(H) "Soda-Straw Rocket" Assessment Rubrics
(I) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types

2.0 Vocabulary

Analyze	consider data and results to look for patterns and to compare possible solutions
Data	facts, statistics, or information
Empirical Evidence	knowledge gained through direct or indirect observation
Engineering	a field in which humans solve problems that arise from a human need or desire by relying on their knowledge of science, technology, engineering design, and mathematics (derived from NRC Framework, 2012).
Explanations	logical descriptions applying scientific information
Graph	a diagram representing the relationship between facts or statistics
Hypothesis	a suggested explanation that predicts a particular outcome based on a model or theory, to be shown true or false
Inquiry	a method of learning scientists use, which includes observing, **questioning**, examining what's already known, planning investigations, using tools to gather, analyze, and interpret data, proposing **hypotheses** and predicting results, and communicating findings (derived from NSES, 1996)
Mission	an operation designed to carry out the goals of the space program
Models	a simulation helps explain natural and man-made systems and shows possible flaws
Prediction	the use of knowledge to identify and explain observations or changes in advance (NSES, 1996)
Questions	scientists asks questions that can be answered using **empirical evidence**
Rocketry	a branch of science that deals with rockets and rocket propulsion

3.0 Procedure

PREPARATION (~15 minutes)

- Set up authorized target for rockets (globe, ball, a round circle on an easel, etc).
- Set up a masking tape line on the floor to establish the launch point
- Access pictures of rockets on the internet: http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html
- Print:
  - Student Sheets (A-F) – 1 per student

Teacher Tips

1. If possible, use ¼" tape for taping the rockets. The smaller size works more easily and can be applied without over-taping areas.
2. Do not distribute the straws until all the students are finished with their rocket and you are ready to have the class begin the launches. Use wrapped straws for sanitary purposes.
3. Have the students line up in a horizontal line to launch the rockets. Depending on the number of students, you may have to have sequential launches take place. An outside venue, cafeteria or gym would work great, as you could spread the students out and allow them to make their measurements easily. Make sure you let them know that no unauthorized launches can be done! They must launch when given permission.
4. Having a launch countdown as a group is always fun! (e.g., 10,9,8,7…)
5. Always provide an authorized target (globe, ball, etc. for students to direct their aim).
6. If students take their rockets home, please advise that no rockets may be launched on the bus!
7. If you use Soda Straw Rockets for other venues (school space nights, open house, etc.), make sure you have a target for the students. Provide a small zip top bag in which students can place their rockets and ask them not to launch in other places.
8. To save time, it is very helpful if you have extra rocket pieces already cut for students who struggle with cutting.

STEP 1: ENGAGE (~20 minutes)

Research common rocket features

A. Blast off! Getting off Earth and toward a solar system destination is exciting. How do we know we can get where we want to go? Engineering design is important to helping us reach our goals. For this engagement, you will be modeling steps in the inquiry process for your students, from observation and questioning to testing and acquiring results, as well as engineering design. As students get older, they will be able to complete these steps on their own.

B. Have students hold their pencils in the air and drop them. *What happened? Does it always happen? What about in space? If an astronaut were to drop a pencil, what would* *happen? Why do you think there is such a difference?* The line of questioning should lead to the answer of: "*What is Gravity?"*

Misconception Alert: The students may say that an astronaut is not experiencing gravity, when in fact they are being pulled toward the Earth while in space. Gravity is an attractive force. While the astronaut is experiencing ***less gravity***, they are not experiencing a complete lack of gravity.

C. Show images of rockets. For initial engagement, you can also begin with "Mars in a Minute: How do we launch to Mars?" as a cartoon teaser for more in-depth content. Research video and images of rockets that NASA sends into space. (http://www.nasa.gov/centers/kennedy/launchingrockets/archives/elv_archive-index.html). Ask students what they may notice about the rockets and the launches. Do they have something in common?

D. Ask the students: How does gravity affect the motion or path of a model rocket?

Teacher Tip: A rocket will be defined in terms of the fuel tanks and fins. The payload of the launch (instruments sent to space) will be contained within the nose cone and will continue out into space on its journey. The fuel tanks and fins will return to Earth and not leave the atmosphere. We are also not discussing the engines found on board missions such as the Space Shuttle or Apollo missions.

STEP 2: EXPLORE (~40 minutes)

Understanding Forces and Design and implement rocket investigation

A. Hand out *(C) Forces and Net Forces Explained* and Explain to students

a. "Similar to gravity, there are a number of forces that push and pull on objects all around us, for example, the object I have placed on your desk, what forces are acting on that object as it rests on the table? Brainstorm ideas with your groups what forces are pushing and pulling on the object."

B. Student will work to answer #1 on *(C) Forces and Net Forces Explained* and share responses. Point out that the table itself is pushing up against the object. Students will probably not believe this to be true. Have student sit in a chair or lean against a wall to experience the feeling of the force pushing against them, the chair pushes up and the wall pushes against them in equal forces to keep them in one spot.

C. As students work to complete #2 and #3 on *(C) Forces and Net Forces Explained*, point out where forces are greater, causing movement. For example, pushing the object means the hand is providing a greater force than the others, therefore allowing the object to move, and in the falling example, the force of gravity is greater than the upward force of the air, allowing the object to fall. This will slowly lead them to the concept of "Net Forces" for the next section.

D. Prior to #4 on the *(C) Forces and Net Forces Explained*, model the difference between a "large" amount of force and a "small" amount of force by pushing on an object harder or softer. Then ask the students "Now, can we represent these forces with a picture." Guide students to the use of arrows to represent the direction of a force and the amount of a force. Create force cards (small arrow and big arrow card) and use check to students understanding by changing the direction the arrow is pointing on the card and having the students identify the direction and amount of force represented.

E. Have students complete #4-#10 of *(C) Forces and Net Forces Explained*

F. Now that students have some background on forces (direction and amount) and gravity, give students the *(A) Soda-Straw Templates* (or pre-cut pieces for very small children) and direct them to write their names, initials, or colorful designs on the fins of the rockets. Review the directions on how to construct their rocket.

Teacher Tip: Have students work in pairs to construct the rocket tubes. One student can hold the tube tight on the pencil and the other student can apply the tape to the paper tube. Students build the rocket on the pencil. Tell them not to remove it from the pencil until you are ready to distribute the straws.

G. Students should select a control for this investigation. Discuss that the purpose of a control is to have something to which you can compare the results. This control should be similar to what you are testing, but something that will be unaffected by the things you are changing. For this investigation, control will be launching from behind the same line and attempting to blow at the same rate.

H. Ask students

a. "*What is the difference between these rockets and the ones we were looking at in pictures and video*?" Ideally, the goal is to help students understand this is a model of a rocket that we will use to test the effect of a force on the distance traveled and path it travels.

I. Prior to launch, have students select the appropriate image/images from *(B) Safety Procedure* that reflect correct safety procedures for launching a soda straw rocket. Discuss which image is most appropriate and why.

J. Students will then place the straw in the opening of their rocket and launch their rocket. Students will then draw and record the distance and path (projectile) the rocket traveled on the *(D) Soda-Straw Rocket Initial Results* and complete the sheet.

K. Students will now brainstorm testable variables that could make their rocket go further. They will record their potential variables on *(E) Soda-Straw Rocket Engineering Design.* Some examples of the variables students could come up with: (but are not limited to) Amount of fuel (how hard they blow), size of the rocket, fin shape or size, barrel length or size, nose cone length, weight added (using paper clips), or angle of launch.

L. Students will complete a variety of launches testing for their variable. Remember, for a controlled experiment, the students should only be changing the variable they are testing, for example, if they are testing how angle will affect the distance traveled, the students will only change and record the angle of launch each time. They should decide what angles and the number of angles they intend to test prior to launching.

M. Students should record the results on their *(E) Soda-Straw Rocket Engineering Design.*

STEP 3: EXPLAIN (~30 minutes)

Drawing conclusions from data and evidence

A. Students will complete *(F) Soda-Straw Rocket Engineering Design Conclusions*. Students might need a reminder or a review of the difference between vertical and horizontal forces from *(C) Forces and Net Forces Explained.*

STEP 4: ELABORATE (~10 minutes)

Consider other possible variables

A. Give students the opportunity to evaluate other possible variables that could affect the flight pattern of a rocket. They may come up with examples such as: angle of launch, # of fins, length of the tube, weighted with paper clips, etc. This exercise helps to build your students to participate in a full inquiry model. If time permits, give them the opportunity to explore some of these different variables and report results out to the class.

STEP 5: EVALUATE (~10 minutes)

Reflect on findings from rocket testing

A. Ask students to complete the *(G) Soda-Straw Rocket Engineering Design Evaluation* so that they can draw conclusions based on evidence from their tests.

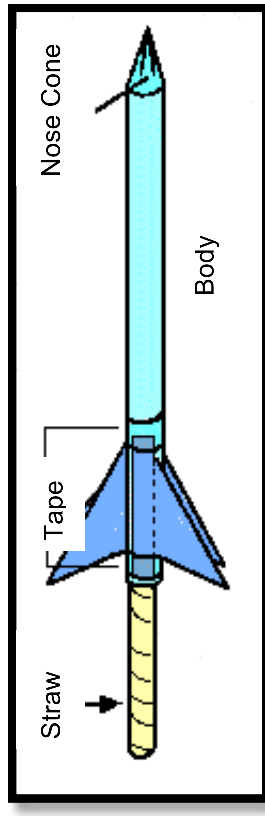
4.0 Extensions

In Step 4: Elaborate, investigate the purpose of nose cones (they hold the payload of rockets) and some of the changes that have to be made to accommodate launching larger payloads into space (e.g., larger rockets, strap-on boosters to add more thrust, etc.).

5.0 Evaluation/Assessment

In the Teacher Guide, use the *(L) "Soda Straw Rocket" Rubric* as a formative assessment that aligns with the NRC Framework, National Science Education Standards, and the Instructional objective(s) and learning outcomes in this lesson.

(A) Student Worksheet. Soda-Straw Rocket Template (1 of 2)



1. Carefully cut out the rectangle. It will be the body tube of the rocket. Wrap the rectangle around a #2 pencil, lengthwise, and tape the rectangle so that if forms a tube.

2. Carefully cut out the two fin units and align the rectangle between the two fins with the end of your body tube. Tape it to the body tube. Tape the tube about ¼" above the end of the tube. That helps to prevent the taping of the fin to the pencil. Do the same thing for the other fin unit, but tape it on the other side of the pencil, so you have a "fin sandwich."

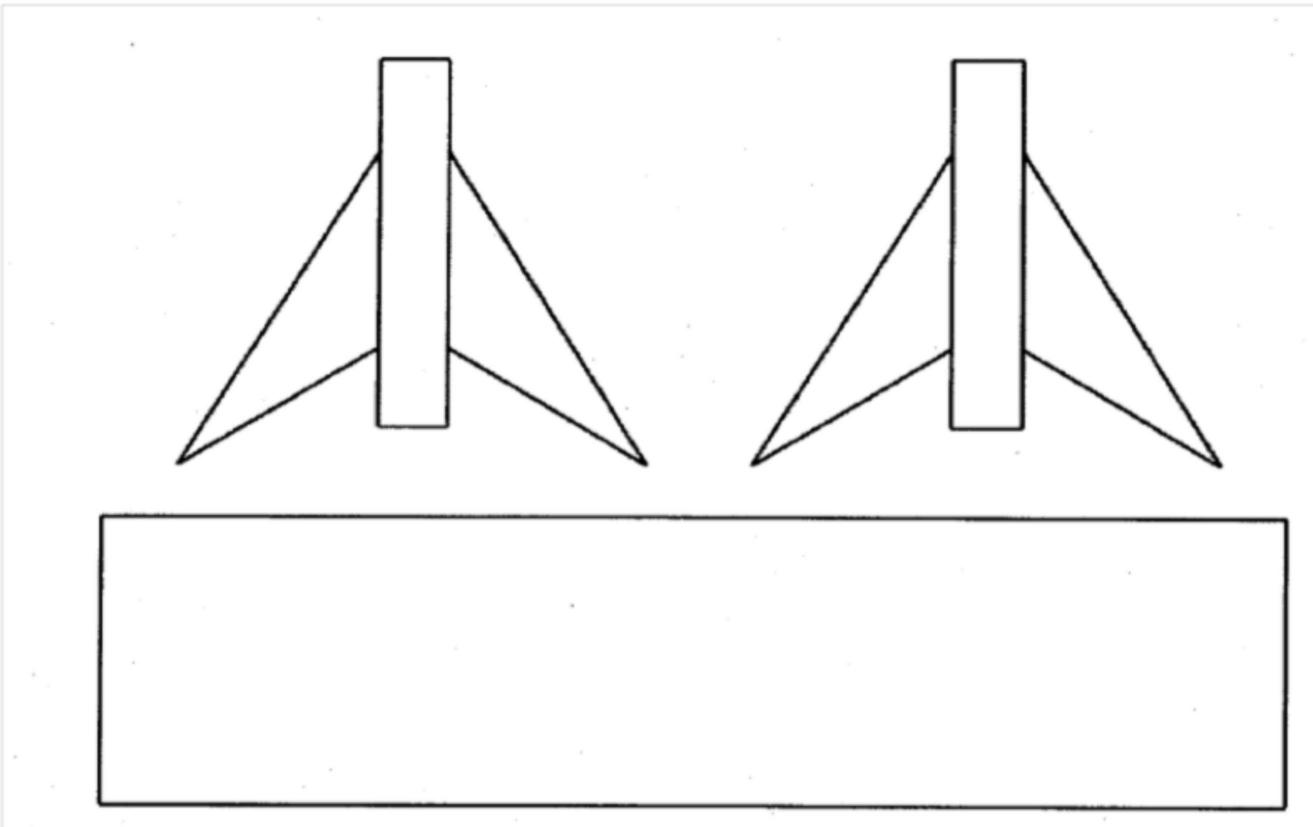
3. Bend one fin on each fin unit 90 degrees so that each fin is at a right angle to its neighbor. When you look along the back of the rocket (near the pencil eraser), the fins should form a "+" mark.

4. At the sharpened end of your pencil, twist the top of the body tube into a nose cone. Measure your nose cone from the base to its tip and record the length on your (B) Data Log and on the rocket itself.

5. Remove the pencil and replace it with a soda straw. Blow into the straw to launch your rocket. Remember launch safety! Never point your rocket at a person. Your goal is to get to your target destination! Record the distance it travels on your (B) Data Log.

(A) Student Worksheet. Soda-Straw Rocket Template (2 of 2)

Soda Straw Rocket Template – Cut these three pieces out carefully.

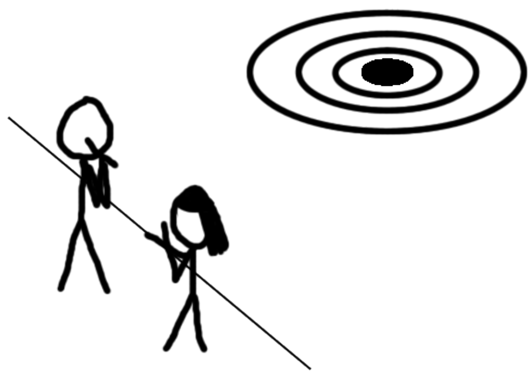


(B) Student Worksheet. Safety Procedure

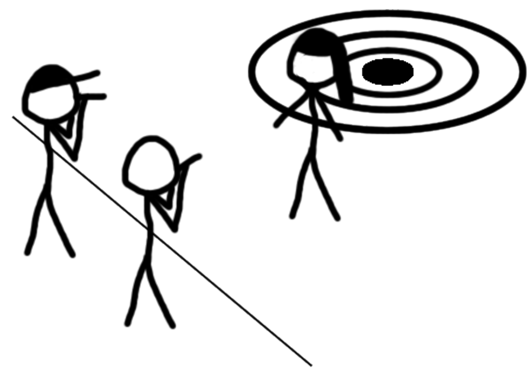
Name: ________________________________

Circle the safest example of how to launch the soda straw rocket:

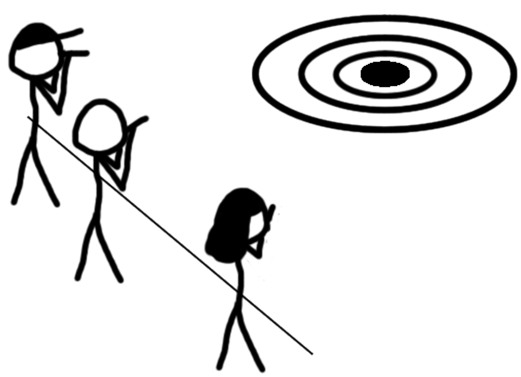
1.



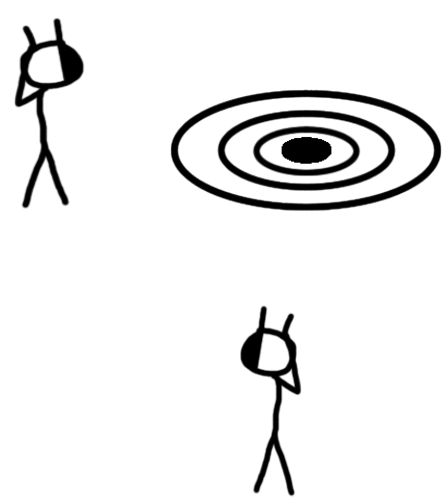
2.



3.



4.



(C) Student Worksheet. Forces and Net Forces Explained (1 of 3)

A ***Force*** is anything that causes an object to change its movement or shape.

1. **Observe the object your teacher has placed on your table. As a group, brainstorm some examples of forces acting on the object as it rests on the table? List or draw these forces in the box below.**

2. **What forces act on the object if pushed to the edge of the table with your finger? List or draw these forces in the box below.**

3. **What forces act on the object if it is pushed off the table? List or draw these forces in the box below.**

******Be prepared to share your ideas with the class.**

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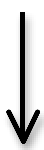
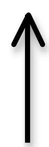
(C) Student Worksheet. Forces and Net Forces Explained (2 of 3)

All forces can be represented as drawings. Usually, forces are represented as arrows.  The arrow shows direction of the force and the size of the arrow show the amount of force. **Bigger arrows mean MORE force, smaller means LESS force.**

4. Let's practice a couple. Circle which of these stands for the LARGEST amount of force to the right?

A.	**B.**	**C.**
		

5. Circle which of these arrows stands for the GREATEST amount of force in the downward direction.

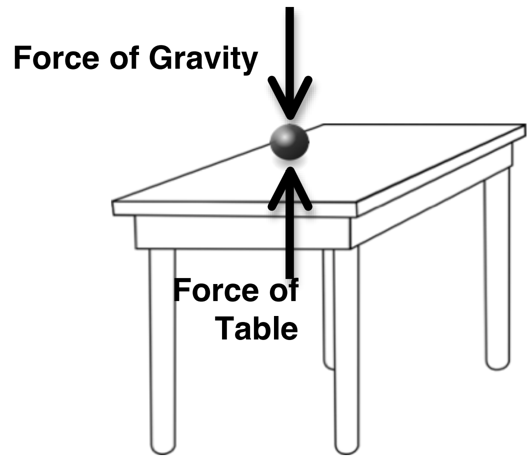
A.	**B.**	**C.**
		

6. Now, let's sort (categorize) and fill in all of the example forces you named in Questions #1, #2, and #3 into these categories:

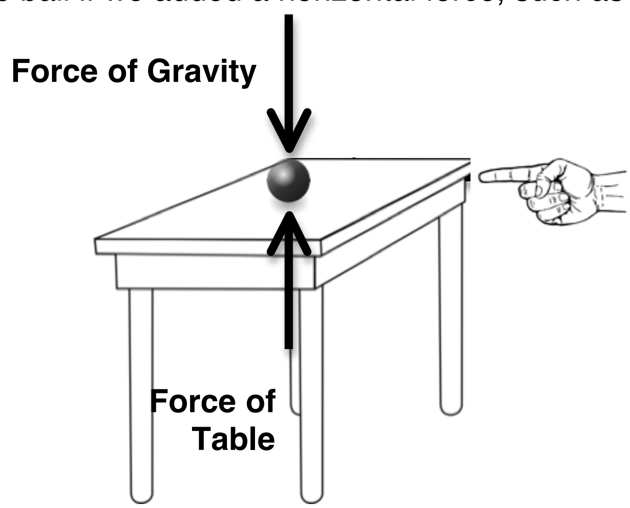
Downward (Vertical) Forces ↓	**Upward (Vertical) Forces** ↑	**Horizontal Forces** ← →

(C) Student Worksheet. Forces and Net Forces Explained (3 of 3)

7. What do you think happens if you combine forces? As an example, look at the diagram below. What will the ball do with these ***equal and opposite*** forces acting on it?



8. Now, what would happen to the ball if we added a horizontal force, such as your hand pushing the ball?



This is called a Net Force. A ***Net Force*** is defined as an overall force acting on an object. When all of the forces are equal and opposite, the net force = zero, the object will not move. But, if the forces are unbalanced, the object will move.

9. Circle the example above that shows a Net Force = Zero?
10. What would have to happen to keep the ball from rolling off the table in #8?

(D) Student Worksheet. Soda-Straw Rocket Initial Results

After launching the soda straw rockets a few times, complete the following:

1. In the box below, draw the path the soda straw rocket took from launch (include stick figure) to landing (include the floor).

2. In the drawing above:
    - Write an "**A**" where you provided the force of air for the rocket
    - Draw an arrow representing the direction of gravity and mark it with a "**G**"
    - Mark all of the areas where the net forces = zero with a "**Z**"
    - **Challenge Question:** Draw arrows on the Z labels showing the direction and amount of force

3. Gravity is a constant pull toward the center of Earth. It is based on the mass of Earth, which is unchanging. Why did the rocket come back down to the ground? _______________________

4. Since gravity doesn't change, will the path of the projectile (soda straw rocket) change? _________________

   What evidence from your experiences do you have to support your answer (you might have to complete more launches to find your evidence)?

   ____

   ____

   How does this evidence support your answer?

   ____

   ____

(E) Student Worksheet. Soda-Straw Rocket Engineering Design

1. What are some ways you could get your rocket to go further (land farther away from the launch line)? These will be called variables.

_______________________________________ _______________________________________

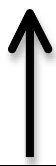
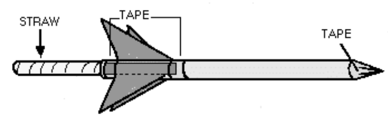
_______________________________________ _______________________________________

Choose one variable you would like to test. Collect data on your experiment, but remember all of the other things you listed must stay the same (be controlled) each time you launch. The only thing (variable) that can change is the one you chose to test. Fill in the data table below, using as many columns and rows you need. Don't forget to label your columns.

	Trial #1	Trial #2	Trial #3	Trial #4	Trial #5	
Distance Traveled (________________)						

(F) Student Worksheet. Soda-Straw Rocket Engineering Design Conclusions

2. Circle the category your variable falls into for types of testing:

		
Vertical (Upward or Downward) Forces Changes to vertical flight	**Horizontal Forces** Changes to the horizontal flight	**Flowing Forces** Changes to how air will flow across the rocket

3. Did your variable affect the distance the soda straw rocket traveled?

Evidence	**Drawing or Graph**
Claim	
Reasoning	

(G) Student Worksheet. Soda-Straw Rocket Engineering Design Evaluation

Name: ____________________________________

1. Did you have any problems controlling certain variables during your experiment? If yes, what were they?

2. What you have identified are called limitations (constraints). What were some ideas your team discussed about how to work around these problems?

3. How did your team decide which idea was the best?

4. Different ideas have to be tested in order to decide which idea solves your problem the best. What types of test launches did your team do to see if the ideas worked?