TEACHER'S HANDBOOK

Applied Science Kit

Exploring Engineering, Space Science, and Sport Science

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Applied Science–Applied science, such as engineering and sport science, is the application of basic scientific knowledge to solve practical problems. Applied science uses and applies information obtained through basic science. Basic science, is research based aimed at understanding fundamental problems.

Engineering

The branch of science and technology concerned with the design, building, and use of engines, machines, and structures.

Lesson 1 – "What Floats Your Boat?"

Ages 6-11

Students will use a small quantity of modeling clay to engineer boats that float in a tub of water. The object is to build boats that hold as much weight as possible without sinking. In the process of designing and testing their prototype creations, students will discover some of the basic principles of boat design, gain first-hand experience with concepts such as buoyancy and density, and experience the steps of the engineering design process.

Lesson 2 – Spaghetti Bridges *this activity takes 2 Days*

Ages 12-14

Civil engineers design structures such as buildings, dams, highways and bridges. Student teams explore the field of engineering by making bridges using spaghetti as their primary building material. Then they test their bridges to see how much weight they can carry before breaking.

Lesson 3 – Paper Airplanes: Heads Up!

Ages 15-19

Students will each build one of four different paper airplane designs, which they test in three trials, measuring flight distance and time. Then they will design and build a second paper airplane design of their own creation, which they also test for flight distance and time. Analysis of experiment data will help them see and figure out what makes airplanes fly farther than others and what can be changed to influence the performance of airplanes.

Space Science

Space science encompasses all of the scientific disciplines that involve space exploration and study natural phenomena and physical bodies occurring in outer space.

Lesson 4 – Train Like An Astronaut: Mission Assignment

Ages 6-11

Astronauts need sturdy spacesuits to help protect them from the harsh environment of outer space. But the protective gear could be bulky, limiting an astronaut's ability to move around. Students will use the gloves to do several manual tasks. They will discover how much more difficult it will be to do simple tasks with bulky gloves that are needed for space.

Lesson 5 – Rocket Power
Ages 12-14
Students construct rockets from balloons propelled along a guide string. They use this model to learn about Newton's three laws of motion, examining the effect of different forces on the motion of the rocket.

Lesson 6 – Mini Mars Cars
Ages 15-19
Students explore the use of wind power in the design, construction and testing of "sail cars," to explore how the wind produced on Mars can be used for power. Students will design, test and redesign small cars made from household materials and use kinematic equations using distance, time traveled, and speed to find acceleration and velocity.

Sport Science

Sports science is a disciple that studies how the healthy human body works during exercise, and how sport and physical activity promote health and performance from cellular to whole body perspectives.

Lesson 7 – Walk, Run, Jump!
Ages 6-11
In this activity, students participate in a series of timed activities using their skeletal muscles. They compare the movement of their skeletal muscle and relate how exercise helps athletes train. Athletes and coaches need to understand how the human body works in order to avoid injury and to help our bodies prepare for sports.

Lesson 8 – Reaction Time
Ages 12-14
Many athletes and people who play sports have a side of their body that is dominant. This is also known as their dominant side, which is a side of the body that a person prefers to use when doing activities. If you write with your right hand, you might also prefer to draw a picture, throw a ball or eat food with the same hand. But have you ever wondered if your right foot is also more dominant than your left foot? What about your right eye and ear? In this activity you'll get to find out whether people have a sidedness—that is, whether they generally prefer to do most activities with one side of their body—and which side that is.

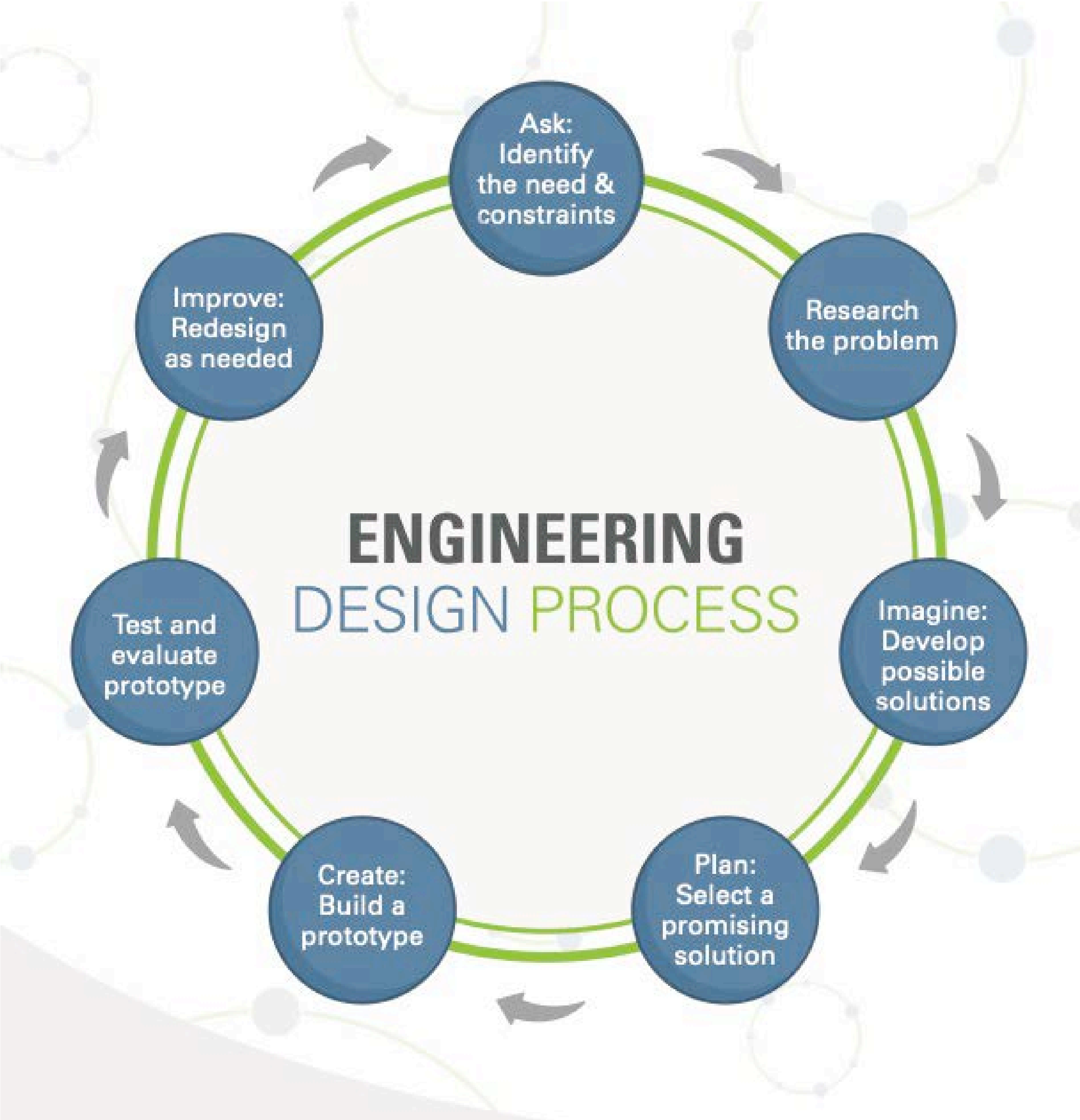
Lesson 9 – Bounce & Collision
Ages 15-19
Students examine how different balls react when colliding with different surfaces, giving plenty of opportunity for them to see the difference between elastic and inelastic collisions, learn how to calculate momentum, and understand the principle of momentum.

Earth Science Kit
NGSS Science Standards Addressed

Lesson	1	2	3	4	5	6	7	8	9
NGSS National Science Standards: K-5									
K. Forces & Interactions: Pushes and Pulls	X	X	X	X	X	X	X	X	X
K. Interdependent Relationships in Ecosystems: Animals, Plants, and the Environment								X	
K. Weather & Climate									
K. Engineering Design	X	X	X	X	X	X			X
1. Waves: Light & Sound									
1. Structure, Function, and Information									
1. Space Systems: Patterns & Cycles									
2. Structure & Properties of Matter	X	X	X	X	X	X			X
2. Interdependent Relationships in Ecosystems									
2. Earth's Systems: Processes that Shape the Earth									
K-2. Engineering Design	X	X	X	X	X	X			X
3. Forces and Interactions	X	X	X		X	X	X	X	X
3. Interdependent Relationships in Ecosystems: Environmental Impacts									
3. Inheritance & Variation of Traits: Lifecycles & Traits							X	X	
3. Weather & Climate						X			
4. Energy	X	X	X		X	X	X		X
NGSS National Science Standards: K-5									
4. Waves									
4. Structure, Function, & Information Processing									
4. Earth's Systems: Processes that Shape the Earth									
5. Structure and Properties of Matter		X	X			X			X
5. Matter and Energy in Organisms and Ecosystems									
5. Earth's Systems									
5. Space Systems: Stars and the Solar System	X	X	X		X				
3-5. Engineering Design	X	X	X	X	X	X			X

Lesson	1	2	3	4	5	6	7	8	9
NGSS National Science Standards: Middle School- Physical Science									
MS. Structure & Properties of Matter									
MS. Chemical Reactions									
MS. Forces & Interactions	X	X	X		X	X	X		X
MS. Energy	X	X	X	X	X	X	X		X
MS. Waves & Electromagnetic Radiation									
NGSS National Science Standards: Middle School- Life Science									
MS. Structure, Function, & Information Processing							X	X	
MS. Matter & Energy in Organisms & Ecosystems									
MS. Interdependent Relationships in Ecosystems									
MS. Growth, Development, Organism								X	
NGSS National Science Standards: Middle School- Life Science									
MS. Natural Selection & Adaptations									
NGSS National Science Standards: Middle School- Earth & Space Science									
MS. Space Systems									
MS. History of Earth									
MS. Earth's Systems									
MS. Weather & Climate									
MS. Human Impacts									
NGSS National Science Standards: Middle School- Engineering, Technology, and Applications of Science									
MS. Engineering Design	X	X	X	X	X	X			X
NGSS National Science Standards: High School- Physical Science									
HS. Structure & Properties of Matter									
HS. Chemical Reactions									
HS. Forces & Interactions					X	X			X
HS. Energy					X	X			X
HS. Waves & Electromagnetic Radiation									
NGSS National Science Standards: High School- Life Science									
HS. Structure & Function									
HS. Matter & Energy in Organisms & Ecosystems									
HS. Interdependent Relationships in Ecosystems									

Lesson	1	2	3	4	5	6	7	8	9
HS. Inheritance & Variation of Traits									
HS. Natural Selection & Evolution									
NGSS National Science Standards: High School- Earth & Space Science									
HS. Space Systems									
HS. History of Earth									
NGSS National Science Standards: High School- Earth & Space Science									
HS. Earth's Systems									
HS. Weather & Climate									
HS. Human Sustainability						X			
NGSS National Science Standards: High School- Engineering, Technology, and Applications of Science									
HS. Engineering Design	X	X	X	X	X	X			X



TEACHENGINEERING

Engineering Design Process

The engineering design process is a series of steps that guides engineering teams as we solve problems. The design process is **iterative**, meaning that we repeat the steps as many times as needed, making improvements along the way as we **learn from failure** and uncover new design possibilities to arrive at great solutions.

Ask: Identify the Need & Constraints

Engineers ask critical questions about what they want to create, whether it be a skyscraper, amusement park ride, bicycle or smartphone. These questions include: What is the problem to solve? What do we want to design? Who is it for? What do we want to accomplish? What are the project requirements? What are the limitations? What is our goal?

Research the Problem

This includes talking to people from many different backgrounds and specialties to assist with researching what products or solutions already exist, or what technologies might be adaptable to your needs.

Imagine: Develop Possible Solutions

You work with a team to brainstorm ideas and develop as many solutions as possible. This is the time to encourage wild ideas and defer judgment! Build on the ideas of others! Stay focused on topic, and have one conversation at a time! Remember: good design is all about teamwork!

Plan: Select a Promising Solution

For many teams this is the hardest step! Revisit the needs, constraints and research from the earlier steps, compare your best ideas, select one solution and make a plan to move forward with it.

Create: Build a Prototype

Building a prototype makes your ideas real! These early versions of the design solution help your team verify whether the design meets the original challenge objectives. Push yourself for creativity, imagination and excellence in design.

Test and Evaluate Prototype

Does it work? Does it solve the need? Communicate the results and get feedback. Analyze and talk about what works, what doesn't and what could be improved.

Improve: Redesign as Needed

Discuss how you could improve your solution. Make revisions. Draw new designs. Fix your design to make your product the best it can be and now, REPEAT!

Engineering

Lesson 1- "What Floats Your Boat?"
Ages 6-11

Overview
Students will use a small quantity of modeling clay to make boats that float in a tub of water. The object is to build boats that hold as much weight as possible without sinking. In the process of designing and testing their prototype creations, students discover some of the basic principles of boat design, gain first-hand experience with concepts such as buoyancy and density, and experience the steps of the engineering design process.

Learning Objectives
1. Students will describe a means to make a material that is denser than water (modeling clay) float.
2. Students will describe the steps of the engineering design process used to create a dense but floatable boat.

Suggested Timeframe
45-60 minutes

Materials Required (each students needs):
- Non-hardening modeling clay, 1/2 stick per student, plus some extra in case any get too wet to mold
- 1 plastic tub of water, at least 6 inches deep, per four or five students
- 100+ large washers to use as weight for boat testing, such as 1.5-inch fender washers; available at hardware stores
- Paper Towel Roll
- 1 Roll of Wax Paper
- 1 Roll of Masking or Transparent Tape
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "What Floats Your Boat" Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation
Very little introduction is required for this fun activity. In fact, this activity works best as an inquiry based lesson.

However, to give students a fun way to gather 'background information' they can complete a Sink or Float lesson to introduce "What Floats Your Boat" activity.

A Sink or Float lesson starts by modeling in front of students (or having students test themselves) a set of different objects placed in a bucket of water and having them predict if it will sink or float. *Use items nearby to place in the bucket for the demo such as a marker, a paperclip, a piece of paper, a pen, etc. Then show the class a half-stick of modeling clay and ask if they think it will float or sink in a clear bucket of water.

After students make their predictions, drop the clay stick into a beaker of water to demonstrate that the clay sinks. Then write on the board, "Engineering design challenge 1: Create an object out of clay that floats." (Then continue with the activity, as described in the Procedures section.)

Vocabulary/Definitions

Buoyancy: The ability to float in a liquid (or rise in a gas).

Density: How much mass a substance has in a given space.

Procedure

Before the Activity

1. Gather all supplies.
2. Get 1 “What Floats Your Boat?” Worksheet, 1 Protective Sleeve, 1 Thin Expo Marker/Eraser for each student pair.

With the Students: Challenge 1 (5-10 minutes)

1. Have each student tape a sheet of waxed paper (~18" long) on the surface of his or her workstation. This makes cleanup much easier, since wet clay gets very messy.
2. If you have not already done so, write on the board, "Engineering design challenge 1: Create an object out of clay that floats." Note that the wording specifies the creation of an object as opposed to a boat. In fact, students who attempt to mold their clay into the shapes of familiar boat hulls will quickly realize that these shapes are less than ideal – at least for clay.
3. Give each student a half stick of modeling clay, and place several tubs of water throughout the classroom. Let students know they can test their objects as often as they like, but advise them to pat the clay dry after testing and before shaping it into a new design.

With the Students: Challenge 2 (15-20 minutes)

1. As students successfully complete Part 1, challenge them with a new goal. Write on the board, "Engineering design challenge 2: Design an object out of clay that can carry the largest load of washers possible." Show students the washers that will be used to make up the load.
2. As students work, encourage them to continue making improvements every time their boats sink. Students may become competitive and want to declare a winner, and it is quite possible that a tie for the number of washers supported will occur. Should this happen, use a balance to determine the actual mass of the washers held, since slight variations exist in the masses of individual washers.

Troubleshooting Tips

If students do not dry their clay adequately between tests of "seaworthiness," the clay may become too wet to work with. Have some extra clay on hand to give to students if their original portions become unworkable.

Assessment

Activity Embedded Assessment

Worksheet: Have the students record their observations and data on their “What Floats Your Boat?” Worksheet. After students have finished their worksheet, have them answer the reflective questions with their partner.

Post-Assessment

Post Assessment: Reflective Questions- You can discuss these as a whole class or small group after the activity. Lead a class discussion by asking questions referring to experiences students had while designing their floating clay objects.

Post-Assessment Continued…
Reflective Questions for group discussion:

- What did you notice while building your boats?
- Why did you make the changes you made?
- What boat designs seemed to work best? What is it about these designs that made them successful?
- What boat designs did not seem to work well? What is it about these designs that made them less successful or unsuccessful?
- How did your boat design change throughout the activity?
- What steps of the engineering design process did you use?

Activity Extensions

- Expect students to have a number of observations about the shapes of successful boats, and express some curiosity about "real" boats and their design features. Assign students conduct library and Internet research to find out about boat designs and how they affect performance. Information on this subject is also covered in the Lesson Background & Concepts for Teachers section of the associated lesson.

Name ____________________________ Date _________________________

Lesson 1: "What Floats Your Boat?"

1. Imagine: What does your boat look like? Design a possible solution to the problem.

Draw a few pictures of your plan in the box below- How will you make a boat out of clay float?

2. Plan: Select a solution. Choose one of your ideas that you drew and predict how many passengers your boat will hold.

Prediction

3. Create & Build: Create your boat out of clay.

4. Test & Evaluate: After you have built your boat, test your boat in the water. If your boat floats, please record how many "passengers" your boat will hold before it sinks. Write your result in the table below.

Actual Result

Did your boat hold more or less than the number of passengers you predicted?

What worked with your boat? What didn't work?

5. Improve & Redesign: Take your boat and fix it. Make changes that you think will help your boat hold more passengers. If you have time, re-test your boat in the water and record your new amount of passengers here.

Actual Result

Engineering

Lesson 2- Spaghetti Bridges
Ages 12-14

(Adapted from University of Colorado)

Overview
Civil engineers design structures such as buildings, dams, highways and bridges. Student teams explore the field of engineering by making bridges using spaghetti as their primary building material. Then they test their bridges to see how much weight they can carry before breaking.

Many people in different branches of engineering work to design and build bridges. Civil engineers are responsible for design and construction of such structures, however they also work with mechanical engineers and material engineers to design the most stable structures. These engineers must consider many variables when creating plans, such as the distance to be spanned, where the bridge is being built, the expected type of traffic it will have to withstand, materials available, budget and what the bridge will look like.

Students will start by watching a video from Science Max called, "Pasta Bridge." Students will then design and construct their own spaghetti bridges and test them over a 2-day period.

Learning Objectives
1. Students will create a design of a bridge structure such as a blue print on plain paper before building.
2. Students will use their design and build their structure out of pasta.

Suggested Timeframe
45-60 minutes over the span of 2 days

Day 1: Student will draw a plan of their bridge design on plain white paper. Students will then place a piece of wax paper over their design and then use spaghetti and glue to construct their bridge. The glue then needs to dry.
Day 2: Testing Day. Students will place their bridges between two tables and add weight to their bridge to see how much weight their bridge can hold before it collapses.

Materials Required (each students needs):
- 1 pound dry spaghetti (noodles and spaghetti)
- Elmer's glue bottle
- Various weights from 5 to 20 pounds
- 2 tables (place 1 foot apart) for bridge to span across
- Rubber Bands
- 1 Roll of Wax Paper
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Spaghetti Bridges" Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

Who do you think creates the human-made structures in our town? Who makes sure they are safe for us to use? (Listen to student ideas.) It is civil engineers who design and create structures such as buildings, dams, highways, skyscrapers and bridges. We can explore the field of engineering by making bridges. We can then test them by applying weights to see when they break. Let's get started by watching a video from Science Max on YouTube called, "Science Max – Pasta Bridge – Season 1" 4 min. 5 seconds [*https://www.youtube.com/watch?v=xN0poIrm0q8*](https://www.youtube.com/watch?v=xN0poIrm0q8)

Procedure

Before the Activity

1. Gather all supplies.
2. Get 1 Plain Piece of White Paper to draw design on, and building materials (spaghetti noodles and spaghetti pieces.

With the Students

Day 1:

1. Show students the available "building materials," including the weights that will be used for testing. Divide the class into teams of students or they can work as an individual.
2. Have teams draw their bridge designs on paper. Make sure that bridges are long enough to span a specified distance between two tables. The span is 1 ft.
3. Once the drawings of their plan are created, have them trace their design plan with a black marker. This will make it easier to see when building.
4. Place a piece of wax paper over their drawing. Create the bridge on top of the wax paper using pasta and noodles. Use Elmer's glue to hold it together. Once completed place them in a safe/secure area to dry.

Day 2:

1. When the bridges are complete, students are going to test their strength.
2. Place a bridge so it spans across the gap between two tables or chairs (1 ft. apart). Place a garbage can or newspapers under the bridge to catch falling debris and make clean-up easier. (Or you can do this activity outside for easy clean up)
3. Apply weights on the bridge, one at a time starting with 5 pounds and working up to 50 pounds, or until the bridge breaks.
4. Conclude with a class discussion to compare results and draw conclusions. Use the **Investigating Questions** as a concluding assessment.

Assessment

Activity Embedded

Worksheet: Have students record how much weight their bridges withstood before they failed. Then, as a class, create a bar graph showing how much weight each bridge held. Discuss which design was able to carry the most weight and why (materials, geometry, use of glue, etc.).

Post-Assessment

Post Assessment: Reflective Questions- You can discuss these as a whole class or small group after the activity. Lead a class discussion by asking questions referring to experiences students had while testing their spaghetti bridges.

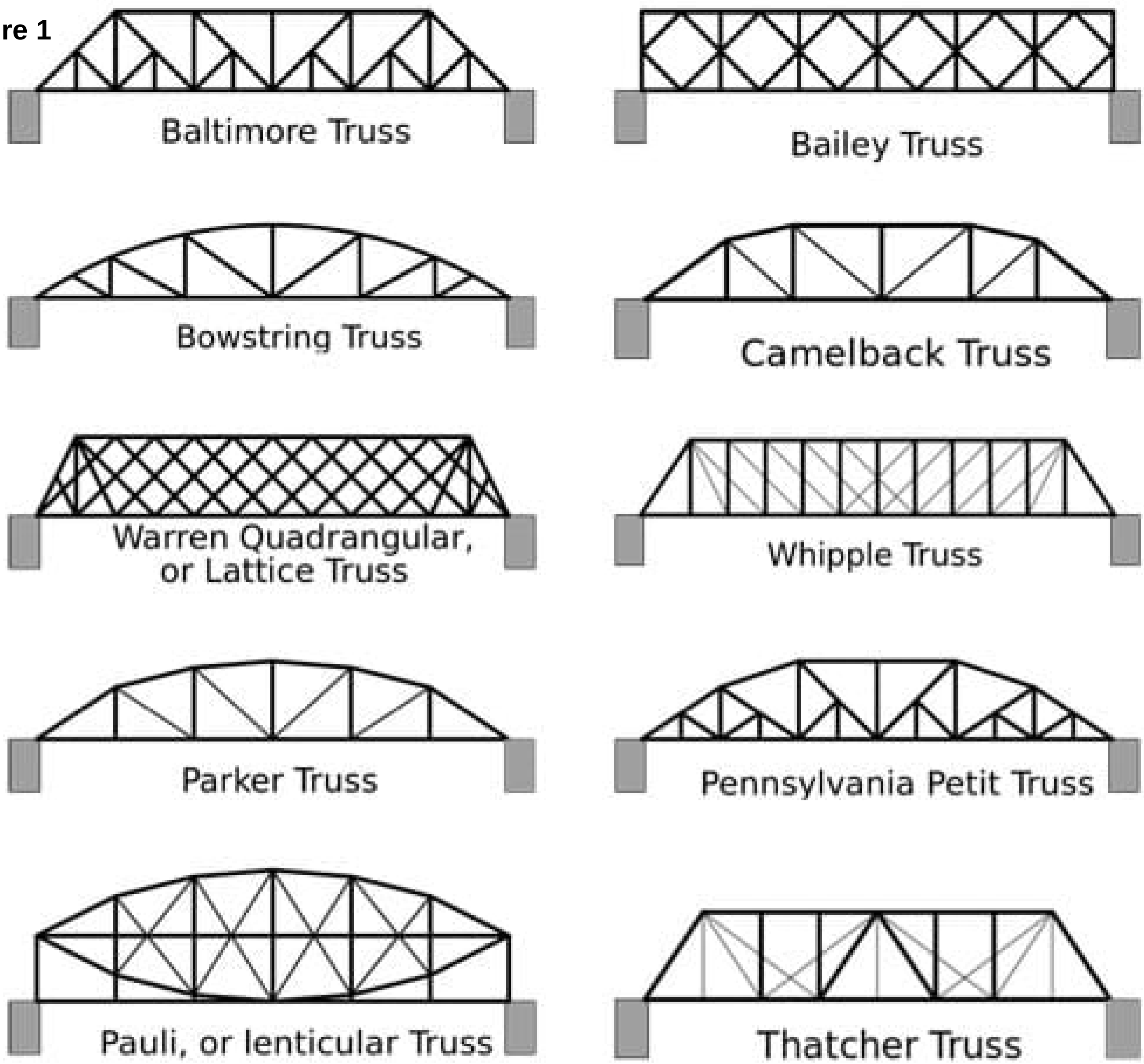
Reflective Questions for group discussion:

- What happened when you added more weights? What does the bridge look like?
- Does adding more height to the bridge make it stronger?
- What are some ways to improve your design?

Activity Scaling
For higher grades, add the additional requirement to incorporate into the design a truss system to strengthen the bridge structure.

Incorporating a construction/assembly pattern makes the bride sides and bottoms stronger. To help generate ideas, show the students the example truss bridge designs in Figure 1. Point out how the designs are made from short straight pieces put together in patterns that often include triangles.

Figure 1



Name ______________________________ Date ___________________________

Lesson 2: Spaghetti Bridges

1. Imagine: What does your bridge look like? Design a bridge that can span across 1 ft.

Draw a few drawings of your plan in the box below- What design do you think can hold the most mass?

2. Plan: Select a solution. Choose one of your ideas that you drew and predict how much weight in grams your bridge can hold.

Prediction

3. Create & Build: Create your bridge out of spaghetti and Elmer's glue.

4. Test & Evaluate: After you have built your bridge, test your bridge by adding weight to it. Keep adding weights (in grams) until your bridge collapses and/or breaks. Record the amount of weight it held before collapsing.

Actual Result

Did your bridge hold more or less than the number of grams you predicted?

What worked with your bridge? What didn't work?

5. Improve & Redesign: Take your bridge and fix it. Make changes that you think will help your bridge hold more weight. If you have time, re-test your bridge and record your new amount of weight here.

Actual Result

Engineering

Lesson 3- Paper Airplanes: Heads Up!

Ages 15-19

(Adapted from University of Colorado)

Overview

Students will start by watching a video from Mystery Doug, "Why Can't Airplanes Fly to Space." Students learn the different airplane parts, including wing, flap, aileron, fuselage, cockpit, propeller, spinner, engine, tail, rudder, and elevator. Then they will each build one of four different (provided) paper airplane (really, glider) designs with instructions, which they test in three trials, measuring flight distance and time. Then they design and build (fold, cut) a second paper airplane design of their own creation, which they also test for flight distance and time. They will then graph the collected class data. Analysis of these experiments with "model" airplanes and their results help them see and figure out what makes airplanes fly and what can be changed to influence the flying characteristics and performance of airplanes.

Engineers often create small-size models of a new product to test its design. This is especially true with airplanes. Model testing tells engineers how a design responds to different air conditions and aircraft shapes, and lets them experiment with the control surfaces that are used to steer the aircraft. Using small models guides engineers to discard prototypes that do not work, which is a smarter option than throwing away full-size (large and expensive to build) aircraft that do not work.

Learning Objectives

1. Students will design and build paper airplanes.
2. Students will use observations of paper airplanes to observe flight.
3. Students will find the average distance of flight trials.
4. Students will explain how engineers often create small sized models of new products to test designs.

Suggested Timeframe

45-60 minutes

Materials Required:
(Each students needs)

- 1-2 sheets of 8.5 x 11" copy paper
- scissors
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 of the 4 paper airplane designs in the Plane Patterns Handout and its associated Plane Design Instructions; vary designs among students
- 1 "Flight Distances Worksheet"
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

(For the class to share)

- 1 Tape Measure and cones to mark every five feet
- 1 Stopwatch (students can use the stop watch on found on google.com)
- 1 Roll of tape
- 1 Glue Stick
- Paperclips
- Completed examples of each of the 4 paper airplane designs

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

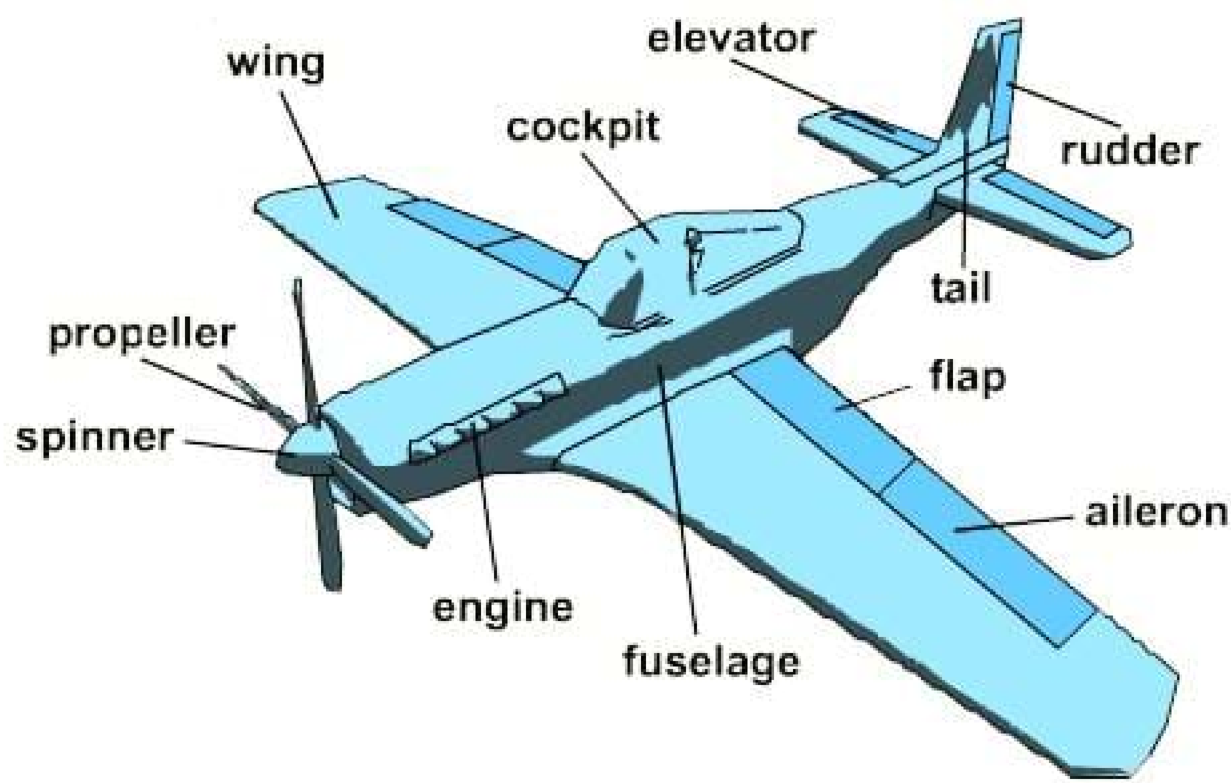
Introduction/Initiation

Let's get started by watching a video from Mystery Doug on YouTube called, "Why Can't Airplanes Fly to Space." 7 min. 1 seconds https://www.youtube.com/watch?v=Zfn1zMatb30

Paper airplanes are gliders. They have a main body, and generally two wings. Some are more complex, with tails, rudders and flaps. The wings compress the air below the paper airplane, creating high pressure, and thus the airplane is able to "sit" and glide on the air.

Moving the rudders, ailerons, or flaps up or down can change the flight path of an airplane. For example, folding down the wing flaps can result in a nosedive and folding up the flaps can point the airplane in an upward direction. (Show the class the Plane Diagram) and have students review and identify the various parts. See Figure 1.

Figure 1



Engineers start with designing and testing several different models of an airplane before they get the approval to build a real one. They typically must work under specific constraints or limits, including the purpose of the airplane. By testing different models of planes, engineers can determine which one is best for distance, speed and other factors.

Today, we are going to learn how to design some simple gliders and airplanes using paper. The class is going to design and build a few different models and determine which paper airplane is the best for distance.

Procedure

Before the Activity

1. Gather materials and give students a copy of the Flight Distances Worksheet.
2. Gather copies of the four different types of paper airplanes in the Plane Patterns Handout, and their instructions in the Plane Design Instructions, one design per student.
3. Make a few models of the four airplane designs to get a feel for how to make them and how they fly.
4. Prepare an indoor (hallway, gym) or outdoor plane testing area—an unobstructed area to throw the planes and measure flight time and distances.
5. Become familiar with the activity vocabulary. List new terms, such as "aileron" and "rudder," on a chart or the classroom board.
6. Prepare the Plane Diagram and Distance/Time Table.

With the Students

1. Conduct the pre-activity assessment brainstorming, as described in the Assessment section.
2. Present the Introduction/Motivation content to the class.
3. Demonstrate one or two paper airplanes. Discuss and list on the board the airplane parts they may know about, and add any terms they do not know, such as "elevator" and "rudder."
4. Then list factors they may know about that would affect flight (for example, plane shape, wing shape, weight, weight at the nose, tails, flaps, rudders, etc.).
5. Explain that they will get to try several designs and see how they work. Hand out a variety of plane designs and their instructions, so each table/general area has an assortment. Give students time to work on the airplanes.
6. Inform students on the method to measure flight distance and flight time, such as the following:
   - Set out cones every five feet and have students estimate their flight distance based on the cones.
   - Have students individually measure their flight distances using tape measures or meter sticks.
   - Have students use a stopwatch to time how long their planes stay in the air.
7. In the plane-testing area, have students test and gather data by performing three test flights with their first plane designs. Direct students to record all three-flight distances on their worksheets.
8. Hand out blank paper, and let students design and test a second airplane. Inform students that this **second design should be their own, original design and entirely different from the first plane design** that was provided to them.
9. Have students test their second designs, again recording the distances and times.
10. Have students compute on their worksheets the average flight times and distances for both plane designs.
11. To conclude the activity, lead a class discussion. Make an effort to use the new airplane parts terminology. Question prompts:
    - What did you learn?
    - What changes did you make in your second airplane design and how did those changes affect the flight distance?
    - Who's plane went farther than five feet? Farther than 10 feet? The farthest of all?
    - Did certain designs go farther than others? Why?
    - What were your flight times? What was the longest flight time?
    - Did certain designs stay aloft longer than others? Why?
    - Did you notice a relationship between average distance and average time? (Expect a weak relationship between time and distance since it is possible for a plane to fly straight up for a while but only travel a few feet forward.)
12. To analyze the class data, first take a poll of the class to compile data counts to complete the Distance/Time Table as an overhead transparency. Direct students to use the larger of their two averages from design 1 or design 2.

Distance	Number of students	Time	Number of students
<2 feet		0-3 seconds	
Between 2 and 4 feet		4-7 seconds	
Between 4 and 6 feet		8-12 seconds	
Between 6 and 8 feet		13-16 seconds	
Between 8 and 10 feet		17-20 seconds	
Between 10 and 12 feet		21+ seconds	
Between 12 and 14 feet			
Between 14 and 16 feet			
>16 feet			

Example blank class data table.

13 Using the class data, have students individually make bar graphs with number of students on the x-axis and distance on the y-axis. Which distance has the largest number of paper gliders that went that far?

14 If time permits, as a class, determine who has the longest time average.

Assessment

Pre-Activity Assessment

Brainstorming: Before starting the activity, have students generate a number of possible ideas about the activity topic. Encourage wild ideas and discourage criticism of any ideas. Ask:

- What are all the different ways you can design a paper airplane?

Activity Embedded Assessment

Worksheet: Have students record on the Flight Distances Worksheet their flight distances and times for both plane designs. Review their data to assess their engagement and comprehension of the experimental testing process.

Post-Activity Assessment

Class Discussion: Ask students to list factors that they noticed affected their airplane model test flights. Record their answers on the board. Ask how they would change their designs if they had more time to work on them. Have them list some of the variables that affect flight (such as the weight of the plane's parts, wing shape, wing length, rudders, ailerons, plane length, etc.)

Pass the Buck: In groups of four, have students brainstorm ideas to design the perfect paper airplane. First, assign one student in the group to be the recorder. Then have someone toss out an idea. Next, another person in the group provides an idea that builds on the first. Go around the group in this fashion until all students have put in enough ideas to put together a design. When they are done, have them share their ideas with the class.

Activity Extensions

For extra math practice, have students create a line or bar graph of their individual plane trials.

Have students complete other challenges with their paper airplanes. Set up a mock landing pad, a target or a hoop to measure plane flight accuracy.

Many websites are available on the topic of paper airplanes and design. If students want to continue to experiment with paper airplane design, suggest they start by looking at the Paper Aircraft Association's excellent website at: http://www.topphotograph.dsl.pipex.com/paamain/index.html

Activity Scaling

For younger students, keep it simple by limiting the designs to one paper airplane prototype design. And, it may be easier if you do not introduce the concept of control surfaces such as rudders and elevators. Also, complete the bar graph as a class or in small groups.

For older students, encourage more complex models and manipulate them more. Encourage students to come up with their own unique paper airplane designs (even for the first plane design), and have them explain their designs to the class in terms of what they changed to improve flight.

Additional Multimedia

A helpful NASA diagram shows the basic airplane parts and their functions; see https://www.grc.nasa.gov/www/k-12/airplane/airplane.html

A database of paper airplanes with easy to follow folding instructions, video tutorials, and printable folding plans. Find the best paper airplanes that fly the furthest and stay aloft the longest. See https://www.foldnfly.com/#/1-1-1-1-1-1-1-1-2

This man tried to break the World Record for paper airplane flight in 2018. Read about it here https://www.wired.com/story/paper-airplane-world-record-watch-live-video/

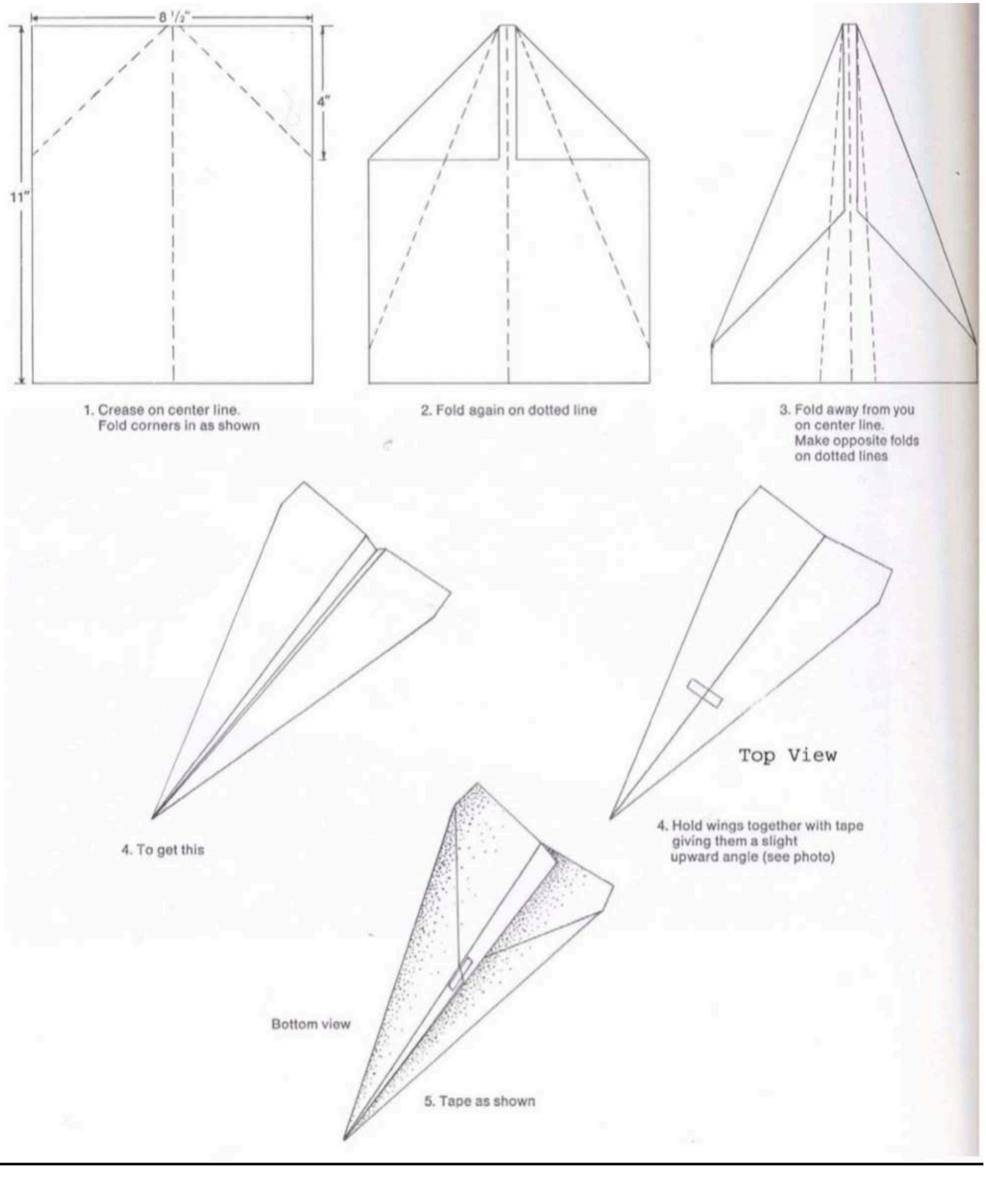
Name ______________________________ Date ___________________________

Lesson 3: Paper Airplanes- Heads Up!

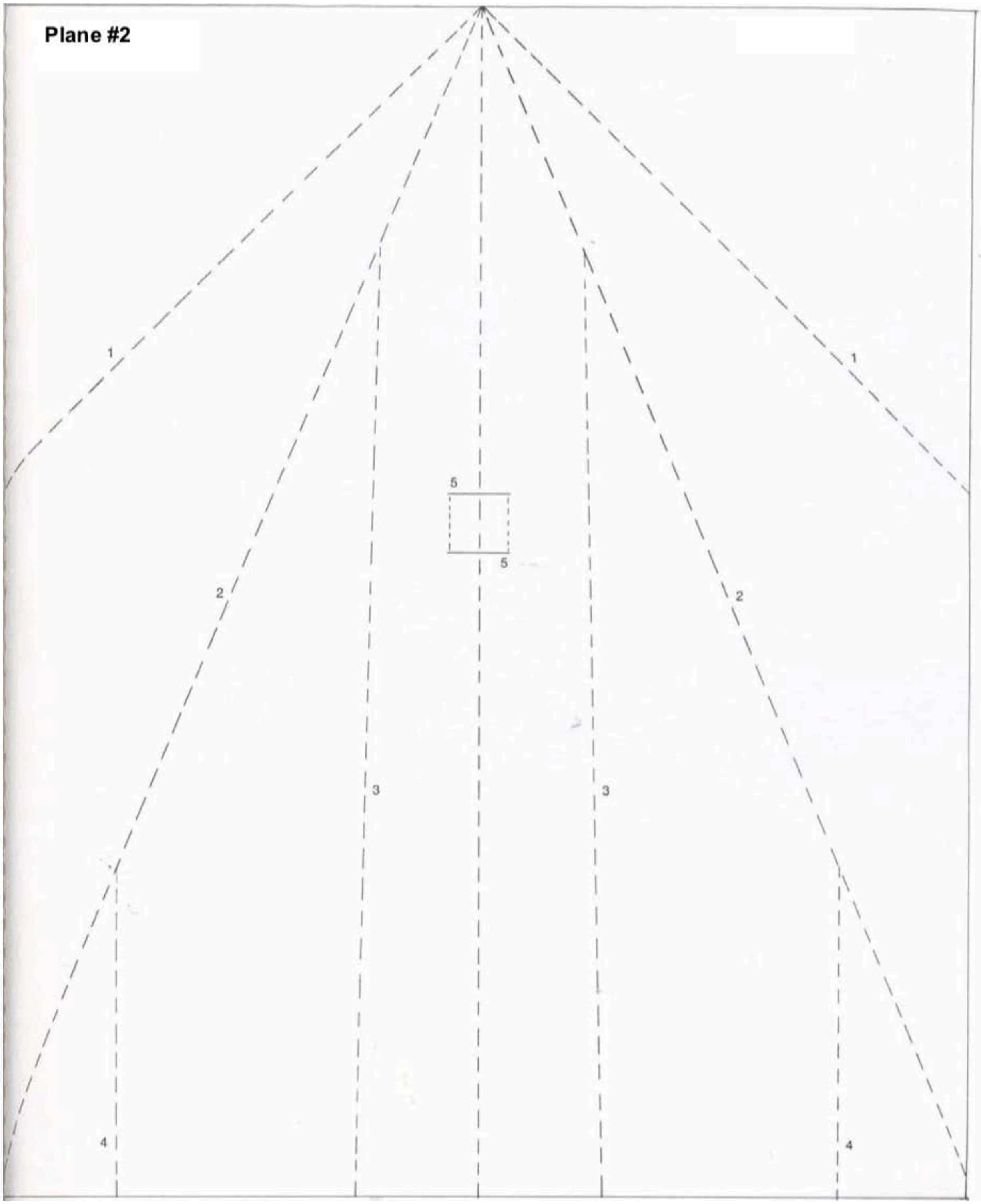
Sample Airplane Designs

Mander, J., Dippel, G., Gossage, H. The Great International Paper Airplane Book, Simon and Schuster, New York, NY, 1967.

Plane #1



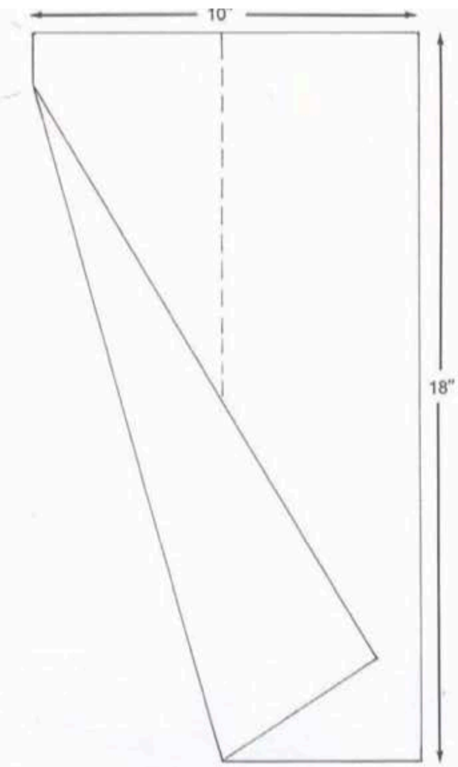
Plane #2



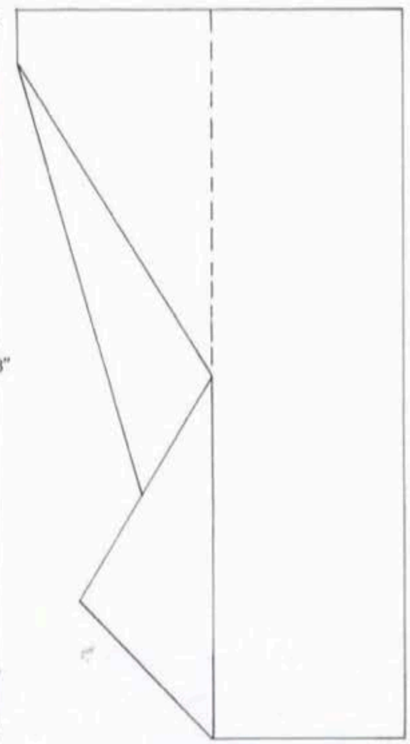
Instructions for Plane 2

Fold at the center-line. Unfold and fold at 1. Hold down and fold at 2. Fold at center and then fold away from center 3 to form wing. Fold up at 3 to form stabilizer. After folding is completed, cut along sold lines 5. Double up on dotted line to lock body together.

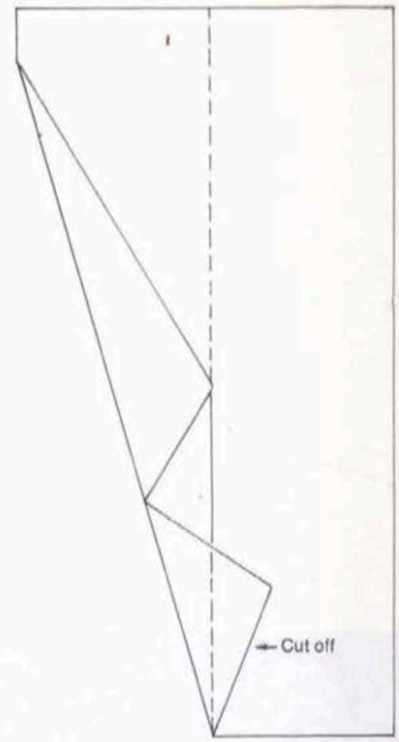
Plane #2



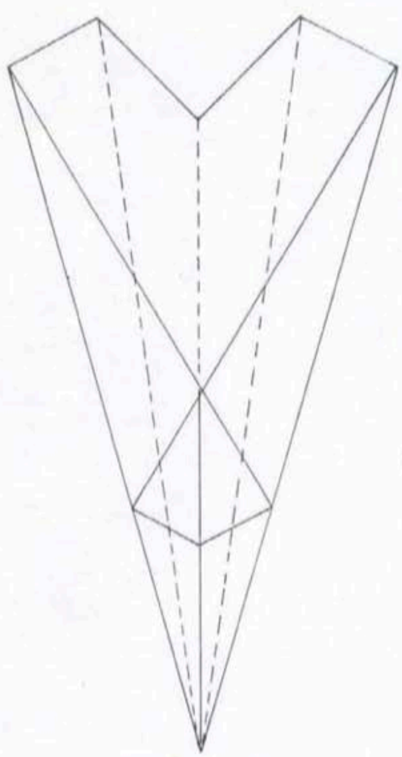
1. Fold on center line.
Open and make fold as shown



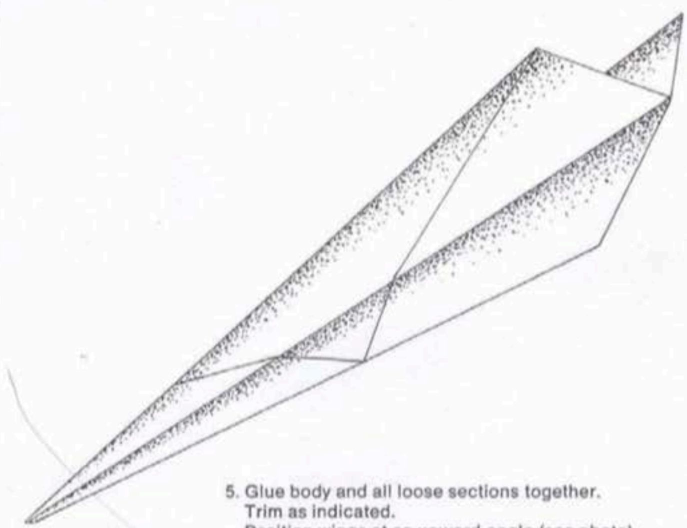
2. Fold back again at center line...



3. And back again.
Trim off part that extends beyond center. Repeat on other half.

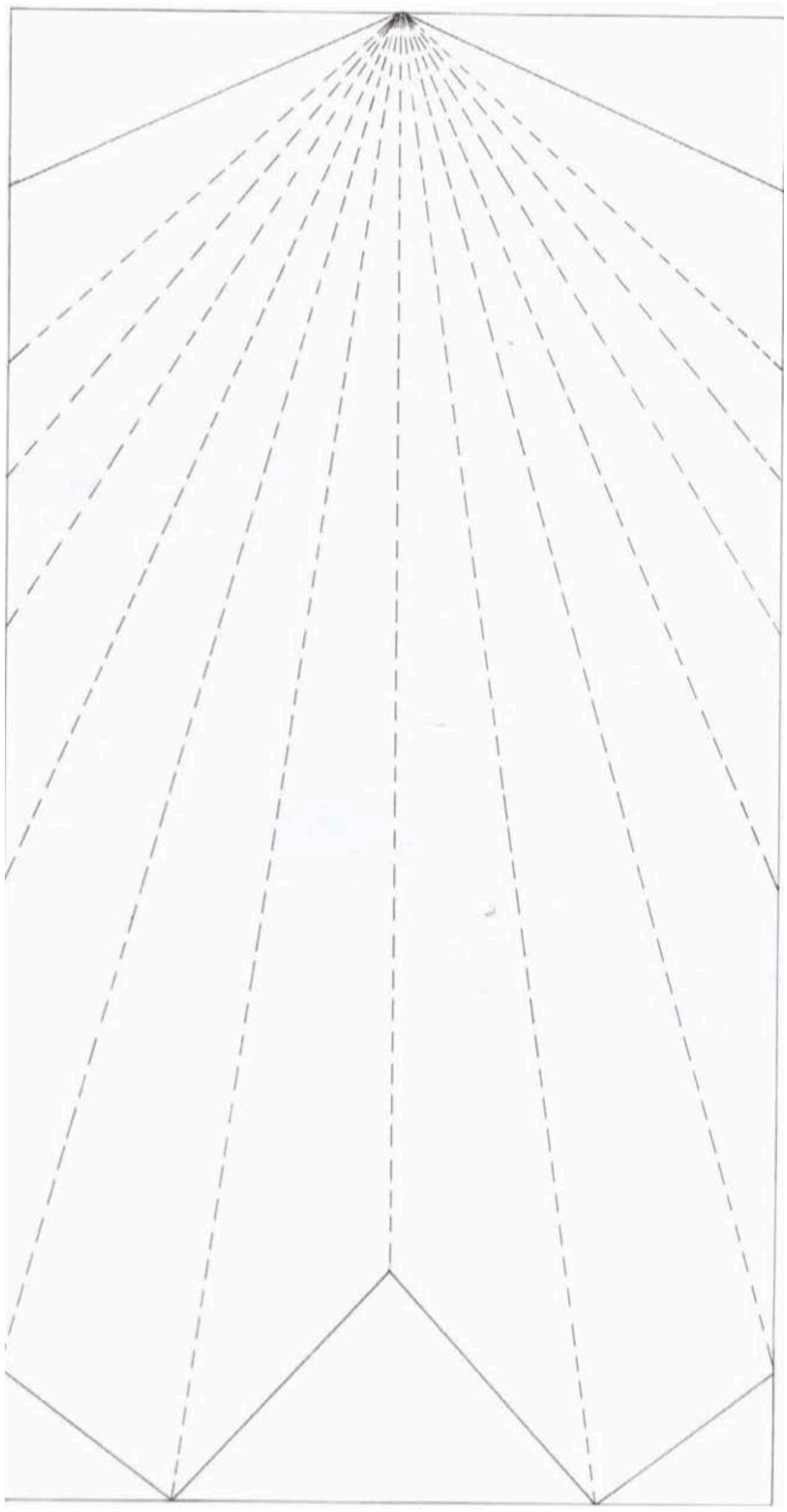


4. Fold down on center line.
And up on sides



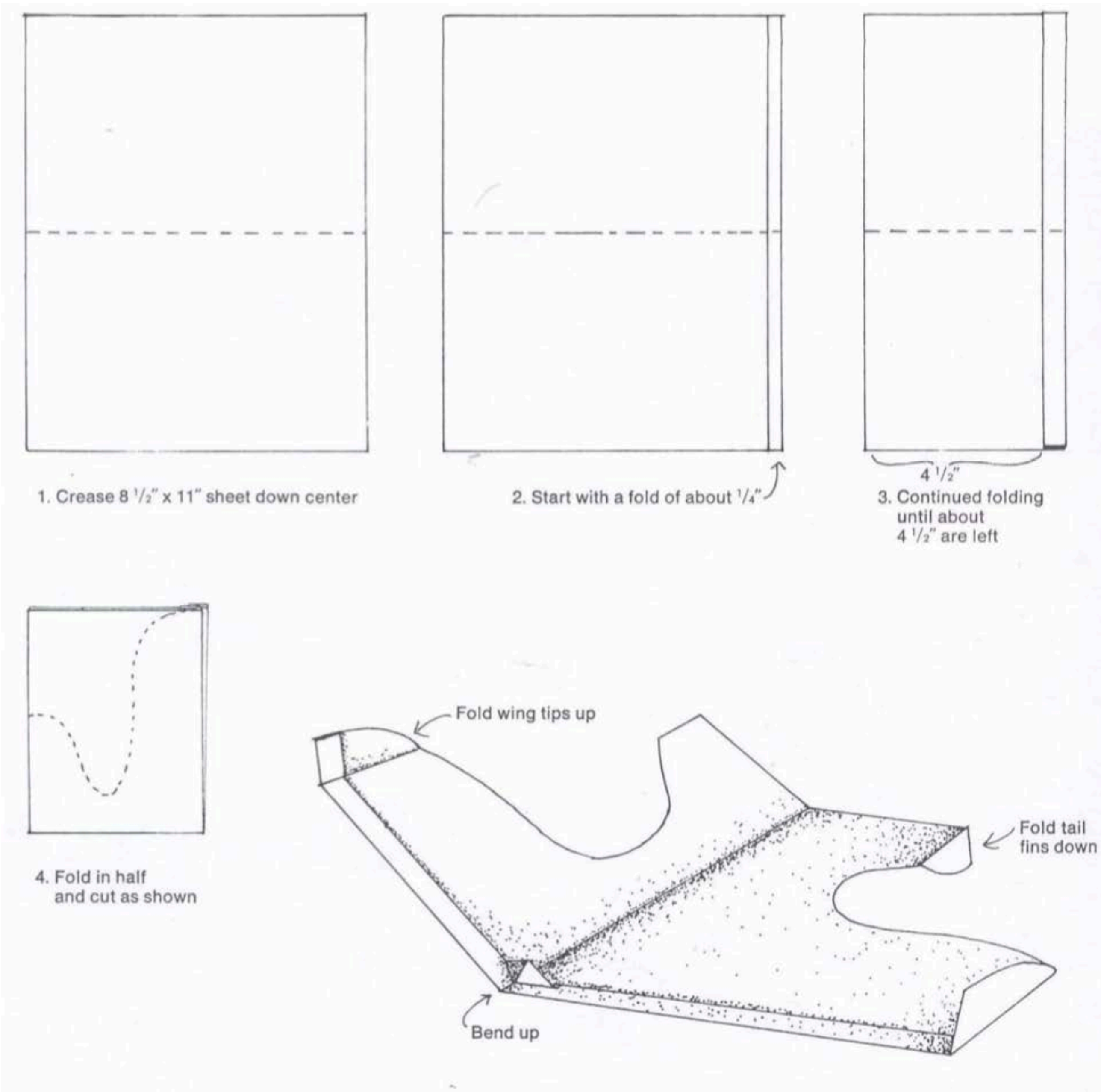
5. Glue body and all loose sections together.
Trim as indicated.
Position wings at an upward angle (see photo)

Plane #3

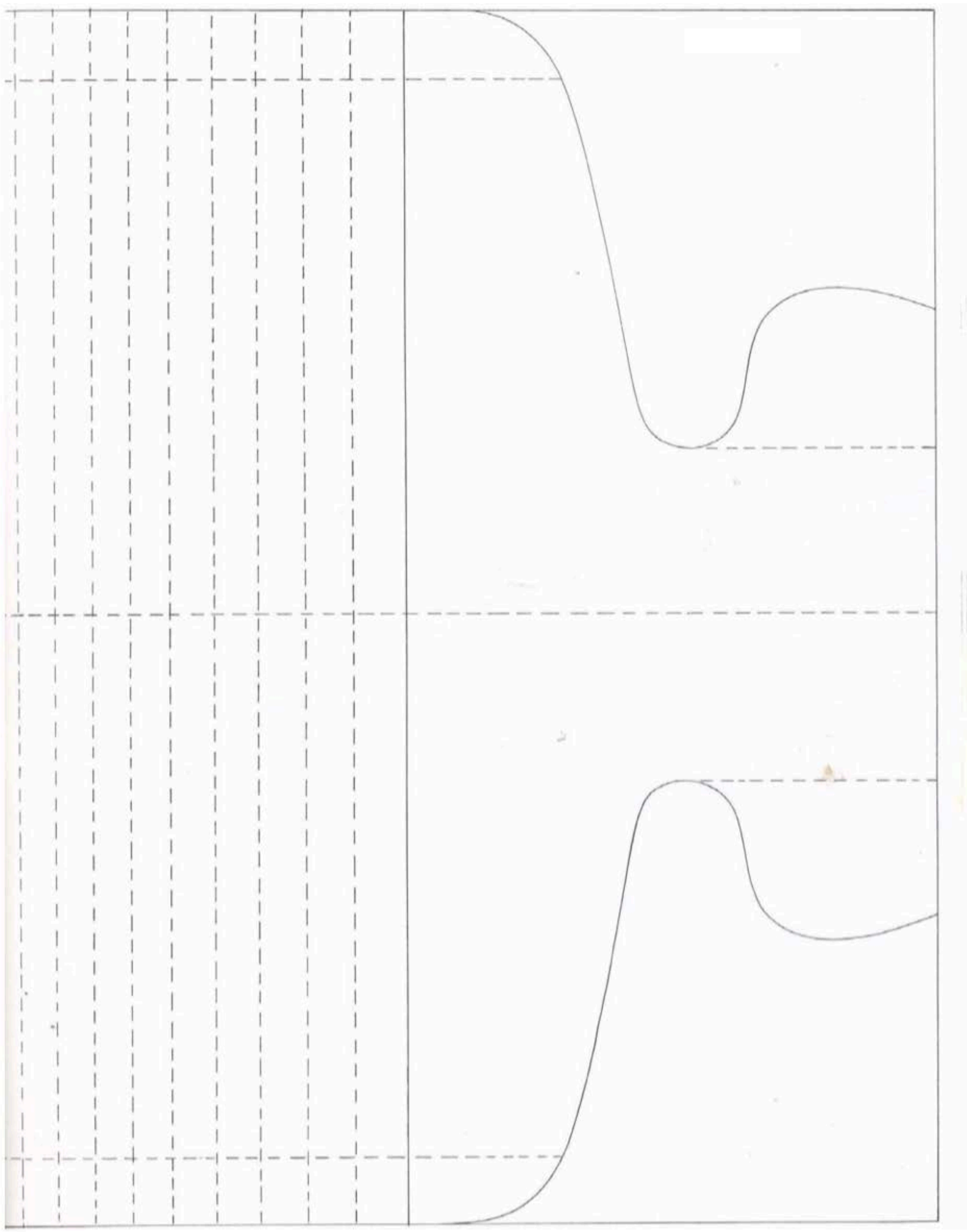


Instructions for Plane 3
Fold like a paper fan.

Plane #4


1. Crease 8 1/2" x 11" sheet down center
2. Start with a fold of about 1/4"
4 1/2"
3. Continued folding until about 4 1/2" are left
4. Fold in half and cut as shown
Fold wing tips up
Fold tail fins down
Bend up

Plane #4



https://www.teachengineering.org/content/cub_/activities/cub_airplanes/cub_airplanes_lesson06_activity1_handout2.pdf

Name ______________________________ Date ___________________________

Lesson 3: Paper Airplanes- Heads Up!

<u>Flight Distances Worksheet</u>

Directions

Fly your airplane three times each, and record the distance of each flight to the nearest foot as well as the amount of time it stayed in the air. Take your three measurements, add them together, and divide by three to get your average flight length.

First Plane Design

Flight #	Length in Feet	Time in Seconds
1		
2		
3		
Average		

Second Plane Design

Flight #	Length in Feet	Time in Seconds
1		
2		
3		
Average		

Class Data (Distance/Time Table)

Distance	# Of Students	Time	# Of Students
<2 Feet		**0 – 3 seconds**	
Between 2 and 4 ft.		**4 – 7 seconds**	
Between 4 and 6 ft.		**8 – 12 seconds**	
Between 6 and 8 ft.		**13 – 16 seconds**	
Between 8 - 10 ft.		**17 – 20 seconds**	
Between 10 – 12 ft.		**21 + seconds**	
Between 12 – 14 ft.			
Between 14 – 16 ft.			
>16 Feet			

Other Observations:

Space Science

Lesson 4- Train Like An Astronaut: Mission Assignment

Ages 6-11

Overview

Students will start by watching a video from YouTube by NASA called, "How Astronauts Put On Space Suits."

Students will learn from the video how astronauts put on the space suit and what does an astronaut wear underneath that iconic suit's shell? In the video, they will visit NASA to learn about all the essentials of space wear, all the way down to the emergency diapers.

While in space astronauts must be able to manipulate tools and objects while wearing a pressurized spacesuit, which includes gloves that completely cover their hands. These thick bulky gloves are worn to protect astronauts from the brutal space environment. As astronauts practice manipulating tools quickly and accurately in their spacesuits, they are improving their dexterity and hand-eye coordination for a space mission.

Following the video, students will put on 'space gloves' and learn what it's like to be an astronaut. Astronauts need sturdy spacesuits to help protect them from the harsh environment of outer space. But the protective gear could be bulky, limiting an astronaut's ability to move around. Students will use the gloves to do several manual tasks. They will discover how much more difficult it will be to do simple tasks with bulky gloves that are needed for space.

Many team members work together to train astronauts for the challenges of space. Teamwork is essential! Astronauts are required to assemble devices on the International Space Station (ISS) and satellites need repairs. Assembly and maintenance in space requires astronauts to have good dexterity and hand-eye coordination.

Learning Objectives

1. Students will discuss the spacesuits that astronauts must wear in order to protect them from pressure differences, temperatures, and radiation in space.
2. Students will experience a few challenges that simulate what astronauts might encounter when they must perform technical skills wearing space gloves.

Suggested Timeframe

45-60 minutes

Materials Required: (Each team/group of 4 students need)

- 1 Pair of Heavy Duty Astronaut Gloves
- 1 Laptop/iPad/Electronic Device (To be used for a stopwatch)
- 1 Piece of String Measuring 10 inches and 10 Beads
- 1 Plastic Container
- 1 Penny
- 1 Bolt/Nut
- 1 Puzzle
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Mission Sheet"
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

Let's get started by watching a video from NASA on YouTube called, "How Astronauts Put On Space Suits." *10 min. 57 seconds https://www.youtube.com/watch?v=VsdoJy8rzZg*

Today, you are going to learn how astronauts feel when they are working on tasks in space outside the International Space Station. You will be working as a team of four to complete a set of tasks all while wearing a pair of thick gloves that are similar to the gloves astronauts wear.

Your team's goal is to complete all four tasks before the other team. One person will wear a pair of thick gloves and complete one task. Once the task is complete, they can take their gloves off and pass them to another person to choose and complete another activity (like a relay race). The first 'team' to complete all four tasks wins.

Procedure

Before the Activity

1. Gather materials and give students a copy of the Mission Worksheet, a protective sleeve, 1 dry erase marker
2. Give each team (4 students): 1 Pair of heavy astronaut gloves, 1 device to use as a stopwatch, 10 beads, 1 piece of string measuring 10 inches, 1 Plastic Container, 1 Penny, 1 Bolt/Nut, 1 Puzzle to complete the astronaut mission.

With the Students

1. Students must each complete a set of four manual tasks. The restrictions are that they must complete the tasks in a limited time while wearing "astronaut space gloves".
2. Give each team a pair of gloves and materials for each of the four activities. Tell the students what the four activities are.
    - They can complete their tasks in any sequence, but they cannot move onto the next task until they complete the task at hand. Once they complete the task, they must record their time on their **Mission Sheet** and then move to the next task.
    - **Task 1- Puzzle**
    1. Dump the puzzle out of its container.
    2. Choose a person to complete the puzzle and have them put on the 'space gloves'. Choose a person to be a timekeeper. They will use the stopwatch to time the puzzle construction from start to finish.
    3. When the time keeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the puzzle as quickly as possible.
    4. When the puzzle is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the puzzle. After the time is recorded, choose a new timekeeper and a new person to complete the next task.
    - **Task 2- Container & Penny**
    1. Get the Container with the lid and a penny.
    2. Choose a person to complete the container & penny task and have them put on the 'space gloves'. Choose a person to be a timekeeper. They will use the stopwatch to time the task from start to finish.
    3. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.

4. The person with the gloves should take the lid off of the container, pick up a penny, and put it in the container. Then put the lid back on the container.
5. When the container & penny task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

- **Task 3- Bolt & Nut**

1. Get the Nut and the bolt.
2. Choose a person to complete the bolt & nut task and have them put on the 'space gloves'. Choose a person to be a timekeeper. They will use the stopwatch to time the task from start to finish.
3. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.
4. The person with the gloves should take the nut off the bolt, and then put it back on.
5. When the container & penny task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

- **Task 4- Bead Necklace**

1. Get the 10 beads and the string to make the necklace.
2. Choose a person to complete the bead necklace task and have them put on the 'space gloves'. Choose a person to be a timekeeper. They will use the stopwatch to time the task from start to finish.
3. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.
4. The person with the gloves should take the beads and string the beads on the string and then tie the string so the beads don't fall off.
5. When the bead necklace task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

3. After all tasks have been complete, have each team complete the rest of their **Mission Sheet** and answering the follow up questions together.

Assessment

Pre-Activity Assessment

Brainstorming: Before starting the activity, have students discuss their "I Notice and I Wonder" ideas after watching the video. Ask:

- What are some interesting things you noticed in the video? Did anything surprise you?
- What are some things you are wondering after watching the video?

Activity Embedded Assessment

Worksheet: Have students record on the Mission Sheet their task times for each activity. Review their data to assess their engagement and comprehension of the experimental testing process.

Post-Activity Assessment

Class Discussion: Ask students to share their follow up questions that they completed as a group following the **Train Like An Astronaut Activity.**

Activity Extensions

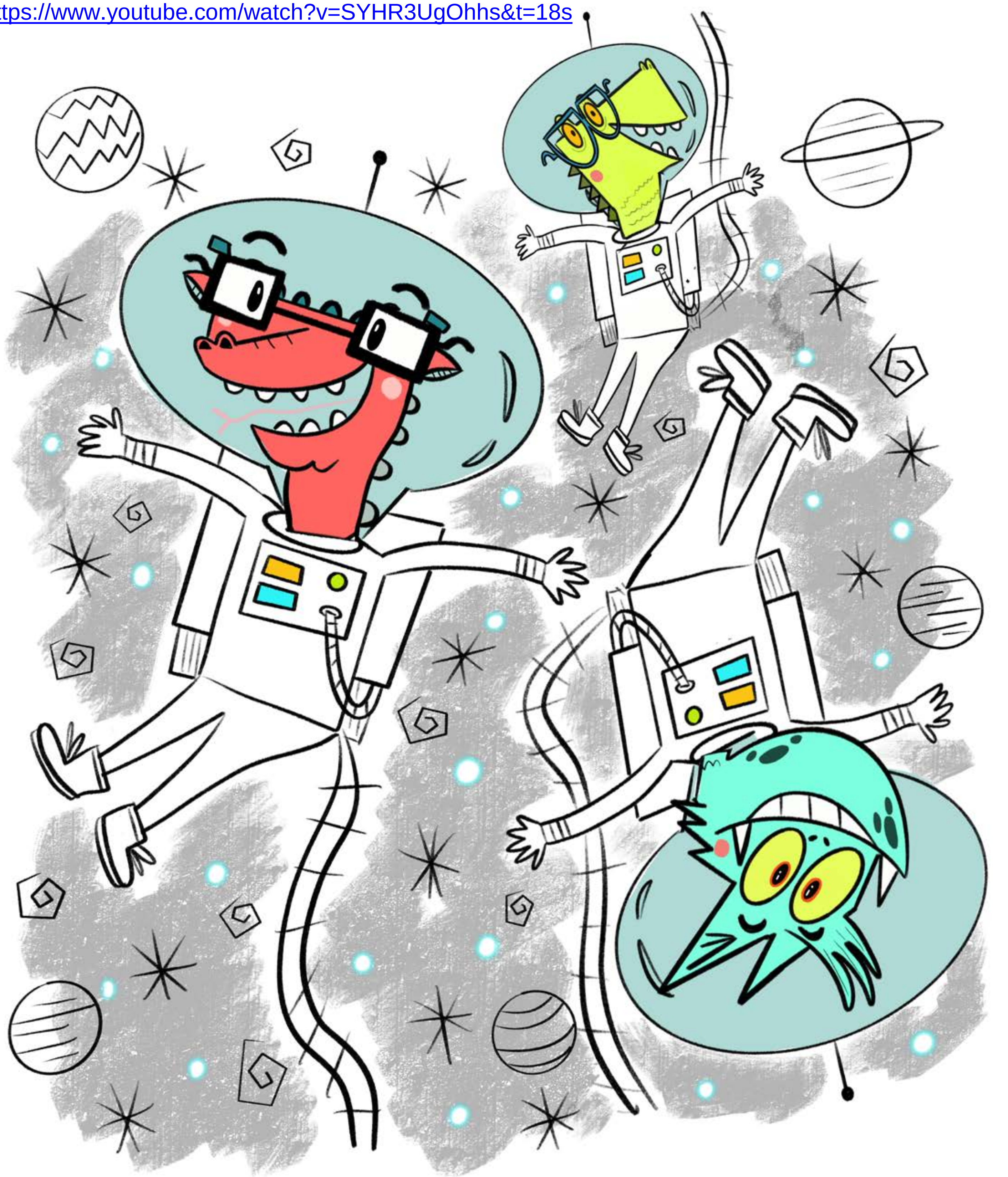
For extra practice, have students try other tasks around the room using the 'space gloves' similar to tasks that were in the YouTube video such as: tying their shoes, writing their name on paper/the protective sleet of the Mission Sheet.

Activity Scaling

For younger students, keep it simple by just having them complete simple tasks like 'writing the name with a pencil' instead of stringing a necklace.

Additional Multimedia

Watch how difficult it is to complete activities with space gloves on by watching a video from NASA on YouTube called, ""Try This: Spacesuit Gloves."
https://www.youtube.com/watch?v=SYHR3UgOhhs&t=18s



Name ____________________________ Date _________________________

Lesson 4: Train Like An Astronaut

Mission Sheet

Directions: *Today, you are going to learn how astronauts feel when they are working on tasks in space outside the International Space Station. You will be working as a team of four to complete a set of tasks all while wearing a pair of thick gloves that are similar to the gloves astronauts wear.*

Your team's goal is to complete all four tasks faster than the other team. One person will wear a pair of thick gloves and complete one task. Once the task is complete, they can take their gloves off and pass them to another person to choose and complete another activity (like a relay race). The first 'team' to complete all four tasks wins.

Task 1- Puzzle

1. When the time keeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the puzzle as quickly as possible.

2. When the puzzle is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the puzzle. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

Task 2- Container & Penny

1. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.

2. The person with the gloves should take the lid off of the container, pick up a penny, and put it in the container. Then put the lid back on the container.

3. When the container & penny task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

Task 3- Bolt & Nut

1. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.

2. The person with the gloves should take the nut off the bolt, and then put it back on.

3. When the container & penny task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

Task 4- Bead Necklace

1. When the timekeeper says, "GO!" they will begin the stopwatch and the person with the 'space gloves' will try their best to complete the task as quickly as possible.

2. The person with the gloves should take the beads and string the beads on the string and then tie the string so the beads don't fall off.

3. When the bead necklace task is complete, the timer should stop the stopwatch. At the bottom of your **Mission Sheet** fill in the time it took to complete the task. After the time is recorded, choose a new timekeeper and a new person to complete the next task.

Data Collection – Record the amount of time it took for your group to complete each task.

	Task 1- Puzzle	**Task 2- Container & Penny**	**Task 3- Bolt & Nut**	**Task 4- Bead Necklace**
Time				

Total Time for all 4 activities: _________________
***Add up the minutes for each task**

Follow Up Questions

1. What did the space glove feel like?

2. What was hardest to do with one glove on?

3. How did that change with two gloves on?

4. How could you change any of the objects so they would be easier to work with?

5. Why is it important that new technology makes it easier for astronauts to move objects and operate equipment?

Space Science

Lesson 5- Rocket Power
Ages 12-14

Overview
Students will start by watching a video from Scholastic by Study Jams called, "Newton's Third Law: Action & Reaction."

Students will learn from the video about Newton's Third Law of Motion and how energy does not change, and that means it is constant. When one object applies force to another, the energy becomes an equal and opposite reaction.

Following the video, students will make and test simple balloon rockets. Students will acquire a basic understanding of Newton's third law of motion as it applies to rockets. Using balloons, string, straws and tape, they will see how expelling gas can propel a rocket. They will test their rockets in horizontal and incline conditions and compare their data. They will also learn about the many types of engineers who design rockets and spacecraft.

Engineers make it possible for humans to leave our planet and explore space. Every discipline of engineering works together to further space exploration. Mechanical engineers design spacecraft components; aerospace engineers design the craft; electrical and computer engineers design the computer and electrical systems; materials engineers design heat shielding materials and spacesuits; chemical engineers design the rocket fuel; etc. Engineers use their combined knowledge of physics, materials, electronics, mathematics, structures and biology to get humans into outer space.

Learning Objectives
1. Students will explain Newton's Third Law of Motion.
2. Explain why a rocket must work harder to move up as opposed to across.
3. List at least two different types of engineers and how they make rockets possible.

Suggested Timeframe
45-60 minutes

Materials Required: (Each team/group of 2 students need)
- 1 Balloon
- 1 Plastic Drinking Straw Cut in Half
- 1 Paperclip
- Masking Tape
- Measuring Tape
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 "Rocket Flight Worksheet"
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

(For the Entire Class to Share)
- Scissors
- Several pieces of fishing line (or fine, smooth string), cut into 30-foot (9-meter) lengths
- Duct Tape

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

Let's get started by watching a video from Scholastic by Study Jams called, "Newton's Third Law: Action & Reaction." 3 min. 15 seconds
http://studyjams.scholastic.com/studyjams/jams/science/forces-and-motion/action-and-reaction.htm

Today, you are going to construct rockets from balloons propelled along a guide string. How does a rocket fly? Can it fly in space and in Earth's atmosphere? What comes out of the back of a rocket? Rockets fly because of Newton's third law of motion. Newton's third law states that for every action there is an equal and opposite reaction. For example: if you are standing on a skateboard and you push against a wall, what happens? The answer is that you and the skateboard would move in the opposite direction. Here the action is pushing against the wall, while the equal and opposite reaction is the movement in the opposite direction.

So, how does a rocket push this gas? Rockets combust (burn) fuels such as liquid hydrogen. The combustion process causes the fuel to get incredibly hot and expand (just like an explosion). This combustion happens inside the rocket, but the hot gas does not fit very well in the rocket and it creates a lot of pressure. Pressure is when something is pushing very hard on something else. In our case, the gas is pushing very hard on the inside of the rocket. Even though a rocket is very strong, too much pressure will cause it to explode. Since we want our rocket to move and not to explode, we let the gas escape. We put a hole in the bottom of the rocket and use a device called a nozzle to direct the gas behind us. This escaping gas is known as exhaust and it is the action in our rocket. The equal and opposite reaction is our rocket moving in the opposite direction. How much power the rocket provides is called thrust.

Do you think it is easier for the rocket to move straight up (away from Earth) or straight across the surface of the Earth? Why might it be harder to move straight up? Gravity is what makes it harder to move up. Gravity pulls objects down toward the center of the Earth. If we want our rocket to reach space, it has to move up and away from the Earth. This means that rockets have to be extremely powerful to overcome gravity. Has anyone ever seen a rocket on television, in a photograph, or in real life? Do you know what makes up most of a rocket? Do you think its suitcases or cargo or scientific equipment or crew quarters for the astronauts? In reality, it is none of these. Amazingly, most of a rocket is fuel. It takes so much work (energy) to get to outer space that most of a rocket is fuel.

So, who is responsible for designing and building rockets? The answer is engineers. Rockets are complicated and usually very large objects. It takes many different types of engineers to get a rocket to work. ***Mechanical engineers*** *create the structure of the rocket and make sure it all holds together.* ***Electrical and computer engineers*** *make sure that all the electrical and computer systems on the rocket function.* ***Chemical engineers*** *design the fuels and make sure the rocket gets all the power it needs.* ***Material engineers*** *design heat-shielding material for the outside of the rocket, as well as the astronauts' spacesuits.* ***Aerospace engineers*** *make sure the rocket is shaped in the best way to cut through the atmosphere and they also make sure all the systems work together.*

Today, you will work as a team to construct balloon rockets and see how they fly when they just need to go in a straight line vs. going up an incline.

Procedure

Before the Activity

1. Gather materials and give students a copy of the Rocket Flight Worksheet, a protective sleeve, 1 dry erase marker
2. Give each team: 1 balloon, 1 plastic drinking straw cut in half, 1 paperclip, masking tape, and a measuring tape. The class will need: scissors, fishing line to span between two chairs, and duct tape.

With the Students

1. Divide the class into teams of two students each. Pass out supplies and worksheets.
2. Have students cut the straw in half, making two shorter straws to share with other teams.
3. Place an equal number of teams at each rocket course. The teams take turns using the course.
4. Have one student from each team inflate the balloon. Twist the open end of the balloon and secure it closed temporarily using a paperclip.
5. Next, have the other teammate tape the straw to the balloon so that it is in the center of the balloon with one end facing the balloon top and the other end facing the balloon opening (nozzle). **See Figure 1.**

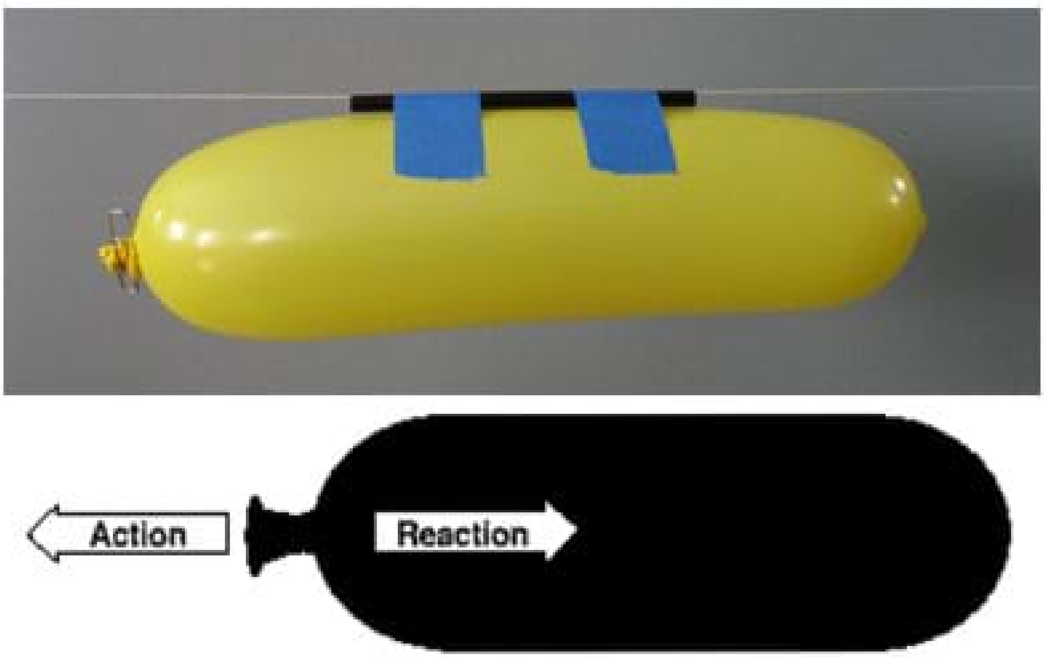


Figure 1. Using a balloon to demonstrate action and reaction.

6. Next, have students thread the string at the unattached end of the course through the straw so that the twisted end of the balloon faces away from the end of the line that is attached to the chair. (**See Figure 2**).

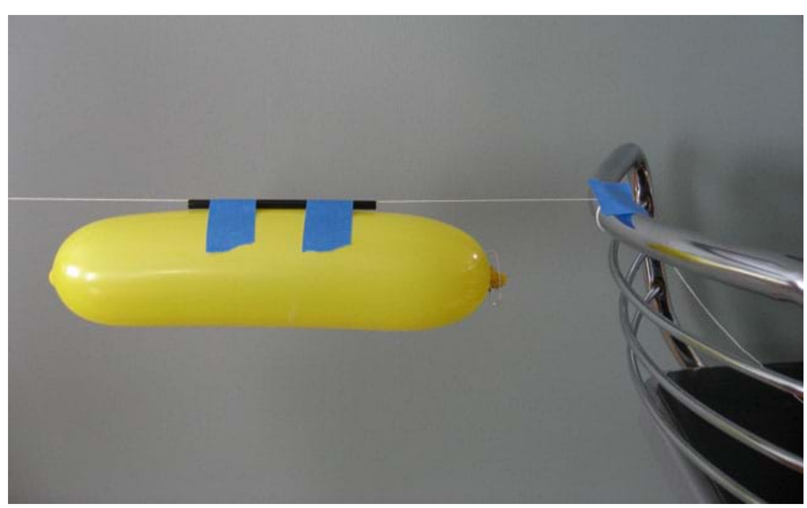


Figure 2. A balloon rocket ready for launch with the string taped to the back of a chair.

7. Instruct one team member to hold the end of the line so that it is taut and level. The other team member makes sure the balloon hangs below the line.
8. With the class counting aloud down from 10, have students release the twisted ends of the balloons at zero.
9. Give the students a minute to determine how far their rocket flew by measuring how far it went on the fishing line.
10. Record the distance traveled on the worksheets.
11. Have the teams take turns using the course until each team has launched their rocket three times, and recorded the distances traveled on their worksheets.
12. Detach the lines from the far end of each rocket course (from the wall or a chair), and move them up higher, so that each is between 6 and 10 feet (2 or 3 meters) above the floor (as high as you can reach).
13. Next, with the lines positioned at an incline and taut, have each group launch their rocket three more times and record the length traveled on their worksheets. Have the students hold the line at the starting end near the ground so the balloons must travel up equal inclines.
14. Have students finish their rocket trials and complete their worksheets.
15. Conclude by holding a class discussion, comparing results, and conducting the post-activity assessment activities described in the Assessment section. See if students understand Newton's third law of motion. Talk about test results in both horizontal and incline conditions and how the expelled air created thrust.

Safety Issues
Advise students not to over-inflate their balloons.

Troubleshooting Tips
While balloon rockets work with any type of thin string, they work best with smooth and/or fine line because friction is minimized. Make sure the straw piece is taped to be parallel with the nozzle and direction of the ejected air. **See Figure 3**

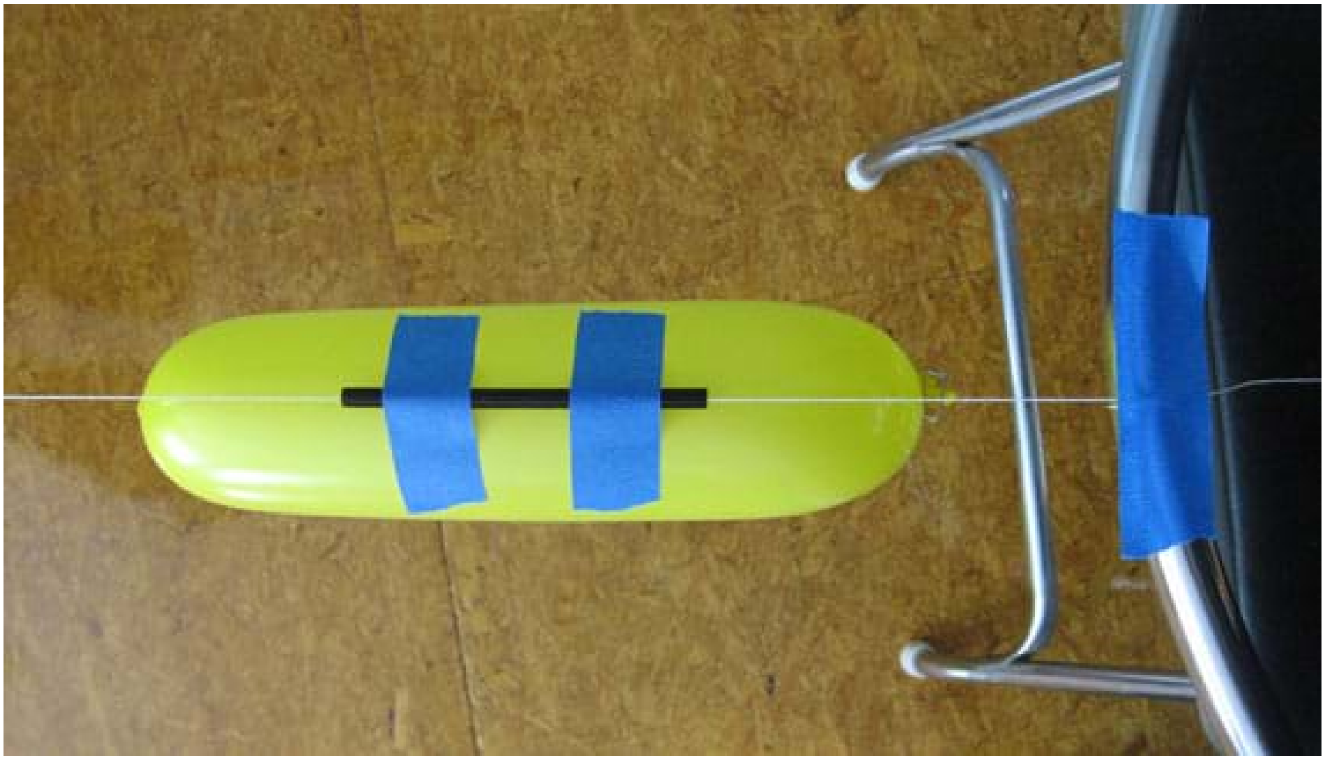


Figure 3

Troubleshooting Tips
Lay down ground rules so that students do not disturb the rocket courses of the other teams. Alternate set-up for repeated trials: Since it is sometimes hard to blow up a balloon again after a straw has been taped to it, you can save on balloons and time by taping a plastic bag (with the open end positioned away from the rocket direction) to the straw and string, and then inserting a blown-up balloon into the bag for each rocket trial. Point out that inserting the blown-up balloon into the plastic bag is like placing the fuel into the rocket structure, but the "nose cone" is not as efficient as a balloon would be. **See Figure 4.**

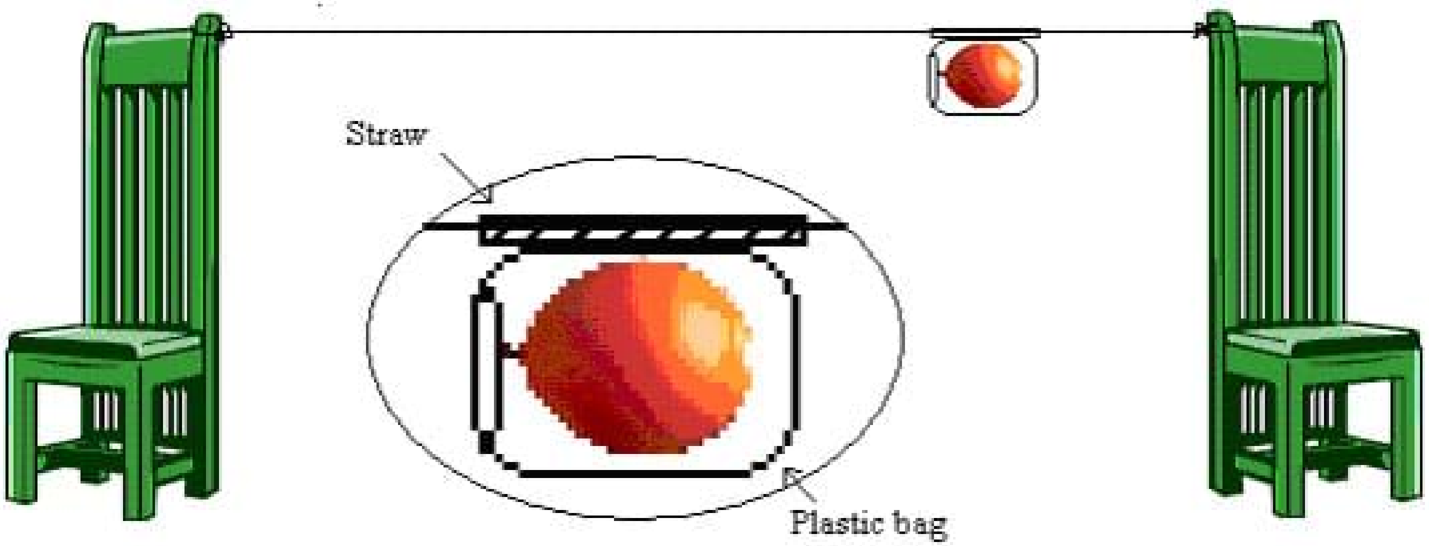


Figure 4. A model of setting up the blown up balloon inside of an open bag

Assessment
Pre-Activity Assessment
Voting: Ask students to vote on which of Newton's three laws applies to the flight of rockets. Tabulate votes on the board. Give the answer: It's a trick question! All three laws apply.

Activity Embedded Assessment
Worksheet: Have students follow along with the activity on their worksheets. After students have finished their worksheets, have them compare answers with their peers. Review their answers to gauge their mastery of the concepts.

Post-Activity Assessment
Class Discussion: Ask students questions from the worksheet. Have the members of each team work together on the answer and everyone on the team must know the answer. Encourage students to include terms that they have learned in the answers.

Activity Extensions
Run the experiment with a bigger or smaller balloon.

Have students fill up their balloons with water and repeat the experiment. Ask them why the balloon moved so slowly (if at all) and why. (Answer: Because the water is heavy, it takes more force to move water than air, and the water spills out of the balloon slowly (compared to air), thus the reaction force is equally as slow as the action force. Note: This is messy! Make sure to follow the water-balloon with a bucket to catch the water or do this activity outside.

Tape pennies to the outside of a rocket to increase its mass. How does increased mass affect the flight of the rocket? (Answer: Because of Newton's second law, the same force exerted upon a larger mass will result in a lower acceleration–the rocket will not go as far!)

Have students re-engineer their balloon rockets again, adding extra features to make the balloon go further. Permit them to use more straw and tape, and more than one balloon. Conduct a race to see which engineering team built the best balloon rocket. Ask that team to explain why their design worked as it did, in terms of Newton's three laws of motion.

Ask students to write journal entries on how the balloon rocket experiment could relate to something else they've encountered. Why are Newton's laws of motion so important in our world?

Activity Scaling

For younger students, complete the worksheet as a class, with different groups using different sized balloons. Use the data from each group's work to construct a plot together, as a class.
Give more advanced students all materials except the worksheet that tells them how to put the rocket together. Ask them to figure out on their own how to construct the rocket.

Additional Multimedia

NASA Quest > Space Team Online: http://quest.nasa.gov/space/teachers/liftoff/newton.html

Name ______________________________ Date ___________________________

Lesson 5: Rocket Power

Rocket Flight Worksheet

Directions

1. Record the distance the balloon traveled for the flights when the string was **flat.**

Flight Number	Distance Traveled	Unit of Measure
1		
2		
3		

2. Record the distance the balloon traveled for the flights when the string was angled **up.**

Flight Number	Distance Traveled	Unit of Measure
1		
2		
3		

3. Did the rocket move further when the string was flat or when it was inclined? Why?

4. Draw a picture that describes Newton's third law of motion: For every action, there is an equal and opposite reaction. (Draw your balloon rocket and use arrows to show the action and reaction directions.)

5. List two different types of engineers who work on rockets.

Lesson 6- Mini Mars Cars

Ages 16-19

Overview

Students will start by watching a video from YouTube by NASA called, “Sounds of Mars: NASA’s Insight Senses Martian Wind.”

Students will listen to Martian wind blow across NASA’s InSight lander. The spacecraft’s seismometer and air pressure sensor picked up vibrations from 10-15 mph (16-24 kph) winds as they blew across Mars Planet on Dec. 1, 2018.

Following the video, students will explore the use of wind power in the design, construction and testing of "sail cars," which, in this case, are little wheeled carts with masts and sails that are powered by the moving air generated from a box fan. The scientific method is reviewed and reinforced with the use of controls and variables, and the engineering design process is explored. The focus of the activity is to design, test and redesign of small cars made from household materials. The activity includes the use of kinematic equations using distance, time traveled and speed to enforce exponents and decimals.

Wind power is one of the simplest and least expensive sources of renewable energy. NASA has been studying Mars to learn more about the planet for future space exploration. By designing wind-powered model cars, students experience the iterative steps of the design process while exploring and gaining a better understanding of how wind power may be utilized by astronauts in the future.

Learning Objectives

1. Students will be able to explain that wind energy is a renewable and sustainable form of power production.
2. Relate how different shapes and angles affect sail (and wind turbine) deign and performance through the testing and improvement stage of the engineering design process.

Suggested Timeframe

45-60 minutes

Materials Required: (Each team/group of 2 students need)

- 2 Straws, to serve as axels
- 4 Life Savers® Mints (Ring Shaped Hard Candies) to serve as wheels
- 8 Plastic Beads (Pony Beads)
- 1 Index Card
- Choice of Mast Material: 2-3 Popsicle Sticks **OR** 1-2 Wooden Skewers
- Choice of Sail Material: 12 x 12 Piece of Aluminum Foil **OR** 12 x 12 Piece of Tissue Paper **OR** 5 Index Cards
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 Mars Car Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

(For the Entire Class to Share)

- Box Fan
- Stopwatch (can be found online using Google Search Engine)

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

Let's get started by watching a video from Scholastic by Study Jams called, " Sounds of Mars: NASA's Insight Senses Martian Wind." *1 min. 39 seconds*
https://www.youtube.com/watch?v=yT50Q_Zbf3s

"Wind power offers one of the simplest, least expensive, and safest sources of renewable power production. NASA Scientists have been studying Mars and the windstorms that occur frequently on the red planet.

Today, we'll be designing and building wind-powered cars to simulate Mini Mars Cars! Who can tell me, in your own words: what is energy? (Example possible answers: The power to do work, heat is a type of energy, what we use when we move, what it takes to make changes to something.) Energy is defined as the ability to do work. Energy comes in many forms, such as chemical, electrical, heat, light, mechanical and nuclear energy.

Does anyone know why wind is considered a renewable source of energy? (Answer: Because we will never run out of wind. Make sure students do not confuse this with the false concept that renewable energy is renewable because we can use it over and over again, which is a common misconception. Instead, enforce the idea that renewable energy sources are renewable because we will never run out of the source, that is, water, solar, wind, etc.)

For fans of "The Martian" novel by Andy Weir, or the film based on that book, Mars dust storms (wind storms) may be a disappointment. Storms on Mars aren't quite as dramatic as the book or the film adaptation portray them to be. While Martian winds at the planet's surface can reach up to about 60 mph (about 97 km/h), this is less than half the speed of some hurricane winds here on Earth and probably not strong enough to rip apart or tip any major equipment, NASA officials said in a statement. [Mars Dust Storm 2018: How It Grew & What It Means for Opportunity]

However, even when winds on the Red Planet reach their highest speeds, wind on Mars isn't quite as powerful as it is on Earth. "Mars' atmospheric pressure is a lot less [than Earth's]. So, things get blown [around], but it's not with the same intensity," William Farrell, a scientist at NASA's Goddard Space Flight Center in Maryland, said in the statement.

Are you ready to apply your design skills to move a car using wind power? This is your engineering design challenge: In groups of two, design a sail (including a mast) to propel your car forward, catching the "wind" from a box fan. You'll get a car base with axles and wheels. You'll design a mast and sail that uses your choice of materials from a provided supply. This is your chance to be creative!

How will you make your sail? How will it best catch the wind? Think of the different masts and sails you have seen. Brainstorm with your teammate. Use your imagination to come up with the best mast and sail shapes using the provided materials.

For this activity, you are acting as engineering teams challenged to design masts and sails. Like engineers everywhere, you'll be following the steps of the engineering design process. Take a look at these steps. In your teams, you'll be brainstorming ideas (imagine, develop possible solutions), planning and sketching your best idea, building and testing your ideas as prototype cars, then redesigning by making improvements and testing again—until you are satisfied with your design and ready to test it against the designs of other teams."

Procedure

Before the Activity

1. Gather materials and give students a copy of the Mars Cars Worksheet, a protective sleeve, 1 dry erase marker
2. Give each team: 2 Straws, 4 Life Savers, 8 Plastic Beads, 1 Index Card, Choice of Mast, Choice of Sail, 1 Dry Erase Protective Sleeve, 1 Thin Expo Marker, 1 Mars Car Worksheet
3. Optional: Build an example of a sail car to show students
4. Mark on the floor with masking tape, a starting line and a finish line (36 inches from start to finish)

With the Students

1. Divide the class into teams of two students each. Pass out supplies and worksheets.
2. In their teams, have students brainstorm, decide on materials and draw sketches of their mast and sail designs (see Figure 3). If implementing a budget constraint, explain the "cost" of the supplies, the team maximum budget, and the requirement to keep track of their expenses as they request materials and redesign.

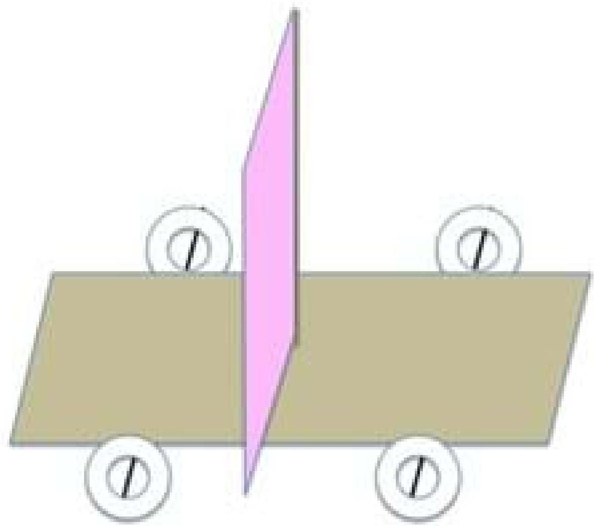


Figure 3. An example drawing of a Mars Car design, showing the car base, mast and sail.

3. After teacher design approval, have one student in each group collect materials.
4. Once they have materials, they are ready to work in their teams to fabricate their sails.
5. As students are ready, test each group's sail car, one at a time, by turning on the fan, placing the car in front of the fan at the start line, and letting go. Direct students to take advantage of these tests to observe their cars' performances and make adjustments in design and materials. For example, fixing wobbly wheels, strengthening the mast and making sure it does not drag on the ground, altering the sail materials, design or orientation, etc.
6. Once teams are happy with their cars' performances, use a stopwatch to time how long it takes each car to travel the track distance (36 inches). Record the times on the classroom board, and fill in the test table and run through the calculations with them. Encourage students who have tested to continue to make improvements as the other teams test their cars.
7. Conclude with a race between the fastest two cars to determine the fastest sail car in the class.
8. Lead a wrap-up class discussion in which students summarize their successful mast and sail design improvements. Also ask students the post-activity questions in the Assessment section.

Troubleshooting Tips
An oversized sail can cause the sail car to tip forward. If this happens, add weights to the base to rebalance the car.

Assessment
Pre-Activity Assessment
Topic Exploration: Ask students the following:

- Think of the windiest day you can remember. How strong did the wind feel? Could it have pushed you over? Do you think the power of the wind could be used for anything other than making you fall down? Have you seen wind push other objects? Did they move fast? Kinetic energy is interesting, because speed is much more important than mass (exponential compared to linear).
- Think of examples of plants and animals that use the power of the wind. What are some examples? (Possible answers: Dandelion, tumbleweed, birds.)
- What do you know about renewable energy? What is your definition of a renewable energy source? Why are oil and coal not considered renewable energy sources?

Activity Embedded Assessment
Test Table: As a class, fill in the Mars Car Worksheet with the team data, doing the calculations together. The students may use a calculator (on a computer) if needed.

Post-Activity Assessment
Quick Wrap-Up: Lead a concluding class discussion with questions such as:

1. What were your design improvements? Which were successful?
2. How can you apply this practice to a real-world sail car construction?
3. (multiple choice) Why are renewable energy sources (such as wind, solar, water, etc.) called "renewable"? Select the correct answer:

- a. They can be used over and over again.
- b. These energy sources do not cost money.
- c. We will never run out of these energy sources (This is the correct answer.)
- d. These energy sources have no disadvantages.

4. Name one advantage of wind energy (Possible answer: It is a renewable energy source that is inexpensive and effective.)

Activity Extensions
Have students explore different sail materials, and even combining the given materials together to make a "composite."

Have students test their sail cars outdoors on a windy day. Have them check the wind speed online and compare it to their car speeds (calculated by timing how long it takes their cars to move a known distance, say 5 or 10 feet).

Challenge students to build larger-scale sail cars. Use different materials, such as LEGO wheels or small model car wheels and axles. Have them compare sail size and weight of the small and large sail cars.

Hold a classroom- or school-wide sail car race!

Activity Scaling
For higher grades, have students also design the base itself. However, note that this changes the controls in the experiment.

For lower grades, do not use the Mars Car Worksheet; instead, simply record run-times on the board for comparison.

Name ______________________________ Date __________________________

Lesson 6: Mini Mars Car

Mars Car Worksheet

Part 1: Calculate your sail car's acceleration! Acceleration is given by:

$$distance = starting\ velocity * time + \frac{1}{2} acceleration * time^2$$

$$d = V_1 t + \frac{1}{2} a t^2$$

The distance is the distance your car travelled, in our case 36 inches. The acceleration is the rate at which the speed of our car changed (that is, from starting at a speed of 0!). The velocity is the speed of the car at the very beginning, which was zero!

Please fill in the blank spots below for time (t) and solve for acceleration (a).

Then, solve for final velocity and reflect on your design.

We know that:

$$d = 36\ inches$$

$$V_1 = 0\ inches/second$$

$$t = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ seconds$$

We can rearrange the equation to solve for acceleration:

$$d = \cancel{Vt} + \frac{1}{2} a t^2$$

$$d = \frac{1}{2} a t^2$$

$$2d = a t^2$$

$$a = \frac{2d}{t^2} = (2 * 36\ inches) / t\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_^{2}$$

$$a = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ inches/second^2$$

Part 2: Calculate your sail car's final velocity! Velocity is given by:

$$ending\ velocity = starting\ velocity + acceleration * time$$

$$V_2 = V_1 + at$$

We know that:

$$V_1 = 0\ inches/second$$

$$t = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ seconds$$

$$a = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ inches/second^2 [From\ part\ 1]$$

Now, just plug all those numbers in and do some math to get your final velocity!

$V_2 = 0\ inches/second +$ _______________ $=$*inches/second*^{2} * _______________*seconds*

V_2 = _______________ inches/second

Part 3: Design Reflection

What improvements did you make to your design?

Did the changes help?

How can we use this technology in the future? Feel free to draw your idea(s).

Lesson 7- Walk, Run, Jump!

Ages 6-11

Overview

In this activity, students participate in a series of timed activities using their skeletal muscles. They compare the movement of their skeletal muscle and relate how exercise helps athletes train. Athletes and coaches need to understand how the human body works in order to avoid injury and to help our bodies prepare for sports.

Learning Objectives

1. Students will explain the three types of muscles in our body.
2. Students will be able to explain why exercise is important to maintaining healthy muscles.
3. Students will be able to explain how our muscles work together.
4. Students will be able to practice using a stopwatch (online using Google).

Suggested Timeframe

45-60 minutes

Materials Required: (Each team/group of 2-4 students need)

- 1 Stopwatch (stopwatch found online using Google search)
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 Walk, Run, Jump! Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

"As we have learned, we all have three types of muscle in our bodies: skeletal, cardiac and smooth muscle. Cardiac muscle is found in our heart, and keeps our blood pumping throughout our bodies. Smooth muscle is found in hollow organs, such as our stomach. Smooth and cardiac muscles are called involuntary muscles, which means we cannot control them just by thinking about it ─ you cannot tell your heart to beat or your stomach to digest!

Skeletal muscles are called voluntary muscles – they are the only muscles that we can control by thinking about them. Skeletal muscles are attached to our bones by tendons, and they help our bones move. Skeletal muscles are the ones we use to kick a soccer ball, dance or even simply hop up and down! Some skeletal muscles that we use frequently are our biceps (teacher: point to upper front arm), triceps (teacher: point to upper back arm), and our quadriceps (teacher: point to front of thighs).

Exercise helps athletes and people like you stay healthy! As we get old, our muscles get weak but if we exercise, we can help our muscles stay strong. Strong muscles are very important because our muscles allow us to do all the fun and important things that we want to do on a daily basis ─ from snowboarding, to playing basketball, to swimming with our friends.

Another very important thing about muscles is that they work in teams – and so do engineers! Today we are going to do some exercises to learn more about our amazing muscles!"

Procedure
Before the Activity

1. Gather materials and give students a copy of the Walk, Run, Jump! Worksheet, a protective sleeve, 1 dry erase marker
2. Give each team: 1 laptop to access a stopwatch on using Google search engine, 1 Thin Expo Marker, 1 Walk, Run, Jump! Worksheet

With the Students

1. Describe the 3 types of muscles (skeletal, smooth, and cardiac).
2. Explain the difference between involuntary and voluntary muscles. Explain which muscles are involuntary and which are voluntary. Ask the students to tell their hearts when to beat (they can't!) and to tell their stomachs to take a break from digesting (which they also won't be able to do).
3. Explain that skeletal muscles are the only muscles we can control by telling them to move.
4. Practice moving some skeletal muscles: ask the class to reach up as high as they can towards the ceiling; touch their toes; hop on two feet; hop on one foot; wiggle their toes; and other similar demonstrations.
5. Tell the students that today the class is going to run some relay races to practice working together in teams and use their skeletal muscles.
6. Break the students into groups and pick one student to be the record keeper for the group.
7. Relay Race: (Can be done outside) Tell the students that each student must walk (or hop or jump) a certain distance- You decide the distance depending on where you're doing the activity, then come back and touch the hand of the next student before they can go. The record keeper should write down the starting and ending time for each race. The students should run four relay races: hopping on one foot, jumping on two feet, walking forwards, and walking backwards.
8. When all the races have been run, the group should work together to figure out the total time for each race, and the total time for all four races.

Assessment
Pre-Activity Assessment
Know / Want to Know / Learn (KWL) Chart: Before the lesson, ask students to write down in the top left corner of a piece of paper (or as a group on the board) under the title, *Know*, all the things they know about *muscles*. Next, in the top right corner under the title, *Want to Know*, ask students to write down anything they want to know about *muscles*. After the lesson, ask students to list in the bottom half of the page under the title, *Learned*, all of the things that they have learned about *muscles*. Ask students to name a few items and write them on the board.

Activity Embedded Assessment
Worksheet: Have the students record their observations on the activity worksheet; review their answers to gauge their mastery of the subject.

- Help students calculate their total time for each race and all four races and answer the questions on the Walk, Run, Jump! Worksheet. Ensure that students understand that the muscles they use for walking, hopping, and jumping are all skeletal muscles.
- Create a list or a graph on the chalkboard showing the total times (from all the groups) for each relay race. Discuss which type of race was the fastest/slowest.

Post-Activity Assessment
Know / Want to Know / Learn (KWL) Chart: Finish the remaining section of the KWL Chart as described in the Pre-Lesson Assessment section. After the lesson, ask students to list in the bottom

half of the page under the title, *Learned*, all of the things that they have learned about *muscles*. Ask students to name a few items and write them on the board. (Possible answers: there are three types of muscles; muscles help us move and do fun things; there are cardiac, smooth, and skeletal muscles; skeletal muscles are voluntary; cardiac and smooth muscles are involuntary; muscles work in teams; engineers help take care of astronauts; exercising helps our muscles stay strong; etc.)

Safety Issues
If racing outdoors, be aware of the possibility of dehydration.
Room/area must be cleared of objects that students could run into or trip over.

Activity Extensions
If time allows, have the students work as a team to see how they could improve their times. Do they have any ideas? Continue to reinforce the idea of voluntary muscle and how they can control when their skeletal muscles move.

Activity Scaling
For upper grades, discuss the role of biomedical engineers in the space program. Discuss cultural attitudes towards exercise and the role of exercise in preventing muscle atrophy. Discuss how developing healthy habits now can help prevent problems in the future. Calculate the average race time per person for each race.

For lower grades, discuss what life would be like without our muscles. Remind them of all the things we would not be able to do without the presence of muscles. Talk about why teamwork is so important.

Additional Multimedia
Fuel Up to Play 60 is a school nutrition and exercise program launched by National Dairy Council and NFL in collaboration with the USDA to improve health and wellness in kids.
https://www.fueluptoplay60.com

Why does a baseball pitcher windup before throwing a baseball? What are some of the biomechanics involved?
Find out by watching this sports science video that explains baseball pitching physics. Learn about velocity, force, arm trajectory and more.
http://www.sciencekids.co.nz/videos/sports/baseballpitchingphysics.html

Name ______________________________ Date ___________________________

Lesson 7: Walk, Run, Jump!

Walk, Run, Jump! Worksheet

Team Members' Names

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

HOPPING start time: __________ Hopping end time: ___________

Total time for hopping: ________

JUMPING start time: __________ Jumping end time: ___________

Total time for jumping: ________

WALKING FORWARDS start time: _________ Forwards end time: __________

Total time for walking forwards: ___________

WALKING BACKWARDS start time: _________ Backwards end time: _________

Total time for walking backwards: __________

Which race was the fastest? _________________

Which race was the slowest? _________________

What was the total time for all four races? ___________

Which type of muscle did you use for all these races?

Circle one: skeletal cardiac smooth

Sport Science

Lesson 8- Reaction Time

Ages 12-14

Overview

Students will start by watching a video from Science Kids by FSN Sport Science called, "Episode 3- Reaction Time- Tennis Test."

Students will find out with this entertaining sports science video that tests athletes hand eye coordination while trying to catch fast moving tennis balls with both hands. What happens when you test the reaction time of some the world's best athletes? How do they compare? Do some sports require better reaction times?

Learning Objectives

1. Students will learn their individual reaction time.
2. Students will investigate which reaction time is faster for them after testing.
3. Students will learn which side of their body is their "dominate side".

Suggested Timeframe

45-60 minutes

Materials Required: (Each team/group of 2-4 students need)

- 1 Stopwatch (stopwatch found online using Google search)
- 1 Ruler
- 1 Piece of Blank Paper
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 Reaction Time Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

"If you write with your right hand, you might also prefer to draw a picture, throw a ball or eat food with the same hand. But have you ever wondered if your right foot is also more dominant than your left foot? What about your right eye and ear—do you prefer to use them more than your left ones? In this activity you'll get to find out whether people have a sidedness—that is, whether they generally prefer to do most activities with one side of their body—and which side that is.

Each person's brain is divided into two sides—the left and right hemispheres. In some cases, one hemisphere may be more active than the other during a certain activity. For example, when someone processes language, one hemisphere is usually more active than the other. Doing this or other activities, however, is not absolutely limited to using one hemisphere or the other, or even certain hemispheric parts. Different brain areas are important and work together for different activities, such as speech, hearing and sight. But if part of a hemisphere is damaged when a person is young, other parts of the brain can often take over doing whatever the damaged regions of the brain used to do.

What do the brain's hemispheres have to do with sidedness? When someone is processing language, one hemisphere is usually working harder than the other. There is also some correlation between the side(s) we use in our brain and the side we use on our body. This preference to use one side of the body over the other is known as sidedness, laterality or left/right dominance."

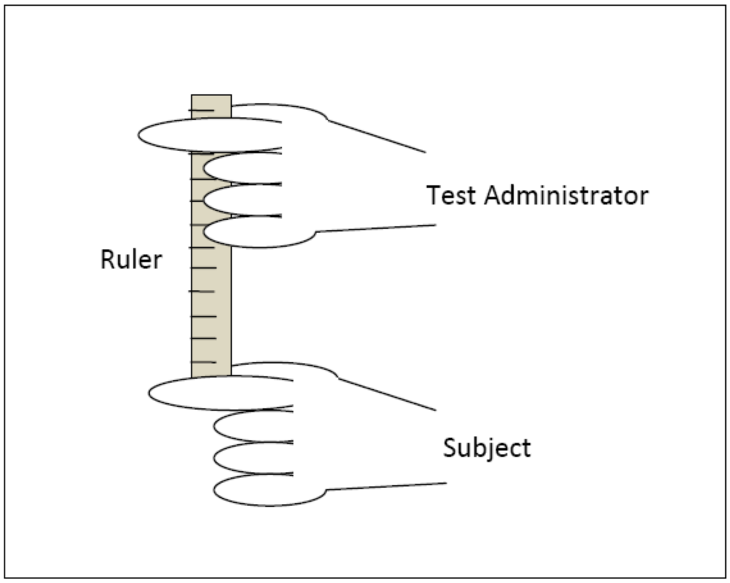
Procedure

Before the Activity

1. Gather materials and give students a copy of the Reaction Time Worksheet, a protective sleeve, 1 dry erase marker.
2. Give each team: 1 laptop to access a stopwatch on using Google search engine, 1 Thin Expo Marker, 1 Reaction Time Worksheet per student

With the Students

1. **Test 1- Eye Test:** Have your partner extend their arms in front of their body. Have them make a triangle shape using their fore fingers and thumbs. Have them bring their hands together, making the triangle smaller (about the size of a coin is good). Find a small object in the room and focus on it through the hole in their hands (using both eyes). Have them try closing just their left eye and then just their right, if your view of the object changed when you closed your left eye mark down 'left', if it changed when you closed your right eye mark down 'right'.
1. **Test 2- Eye Test:** Give your partner a blank paper and roll it into a tube and ask them to look at a distant object through it. *Which eye do they use to look through the tube?* Record the result in your data table in the "Eye" row, under your partner's name.
2. **Test 3- Hand/Arm Test:** Ask your partner to write their name on a piece of paper. *Which hand do they write their name with?* Record the result (writing either "Right" or "Left") in your data table in the row labeled "Hand," in the column under the volunteer's name.
3. **Test 4- Hand/Arm Test:** Place a coin/or object on the floor directly in front of your partner. Ask them to step onto the coin. *Which foot is used to step on the coin?* Record the result in your data table in the "Foot" row, under your partner's name.
4. **Test 5- Ear Test-** Have your partner 'pretend' to answer a phone. *Which ear do they put the fake/imaginary phone up to?* Record the result in your data table in the "Ear" column, under your partner's name.
5. **Test 6- Leg/Foot Test-** Have your partner pretend there is an imaginary ball on the ground and kick it. Which foot do they use?
6. **Test 7- Leg/Foot Test-** Have your partner stand with both legs together. Give them a **gentle** tap/nudge to see what foot they take a step with first. Is it their right foot? Or left foot?
7. **Test 8- Hand/Eye Test-** Action Reaction Test
   - Hold a 12 in. ruler near the end with the highest number and let it hang down. Zero inches should be pointed to the ground. Have your partner put his/her dominant hand at the bottom of the ruler, not touching it, and be ready to grab the ruler when it drops.
   - Tell your partner that you will drop
   - the ruler sometime in the next five
   - seconds with no countdown warning
   - and that s/he is to try to catch the
   - ruler as fast as s/he can after you
   - drop it. [See diagram ➔]



Test 8- Hand/Eye Test- Action Reaction Test Continued…

- Record in the data table the level on the ruler (centimeters or inches) at which your partner catches it.
- Repeat this test with the same subject for a total of three times. Vary the time of dropping within the five-second "drop-zone" so the subject cannot guess when you will drop the ruler.
- Now try a "countdown" case: Conduct the same test with the addition of a countdown warning. Tell your partner that you will drop the ruler at the count of three and say: 1… 2… 3 and drop it when you say 3.
- Record in the data table the point on the ruler where the partner caught it for this trial. Repeat this test with a countdown with the same partner for a total of three times.

Assessment

Pre-Activity Assessment

Discussion: Have a discussion with the students about whether or not they have a 'preferred' hand for writing, kicking a ball, playing sports.

Activity Embedded Assessment

Worksheet: After testing their reaction times, have students share and discuss as a class their findings. Then either have students answer the six Response & Reaction Worksheet results and analysis questions in writing to be turned in for grading or lead a class discussion using the questions as prompts. Consider student answers and/or discussion contributions to gauge their comprehension.

Post-Activity Assessment

Results/Analysis Questions: Wrap up the lesson by discussing with students their responses to the results and analysis questions that can be found on their Reaction Time Worksheet.

You probably already know that most people are right-handed. In fact, roughly 70 to 90 percent of people are right-handed. From this activity, you probably saw that most people who are right-handed are also right-sided overall. That is, they mostly prefer to use their right foot, eye, and ear as well. But there are certainly exceptions, particularly with eyes and ears—a right-handed person may prefer using their right foot and right ear, but prefer their left eye over their right one. Similarly, a right-handed person may prefer their right foot and eye, but prefer their left ear. You may have seen a similar trend with left-handed people. Because the majority of people who are right-handed are also right-footed, in some cases where a person writes with their right hand but prefers to use their left foot, they may have been predisposed to being left-handed but were raised to use their right hand.

Overall, whereas the vast majority of the global population is right-handed, it's thought that a smaller percentage is right-footed, an even smaller percentage is right-eyed, and yet an even smaller percentage is right-eared (perhaps a little over half), but this trend is unlikely to be visible using only five volunteers. Why might people have a weaker preference for an eye or ear that matches their dominant side? Perhaps one ear or eye is stronger than the other.

Additional Multimedia

Dowshen, Steven. What Are Reflexes? Last updated September 2010. Kids Health from Nemours. Accessed April 16, 2013. http://kidshealth.org/kid/talk/qa/reflexes.html

List of reflexes (alphabetical). Last updated November 3, 2012. In Wikipedia, The Free Encyclopedia. Accessed April 16, 2013.
http://en.wikipedia.org/w/index.php?title=List_of_reflexes_(alphabetical)&oldid=521175984

Mental chronometry. Last updated March 2, 2013. In Wikipedia, The Free Encyclopedia. Accessed April 16, 2013. http://en.wikipedia.org/w/index.php?title=Mental_chronometry&oldid=541675578

Your Sense of Touch. The Senses, Oracle ThinkQuest. Accessed April 16, 2013. http://library.thinkquest.org/3750/touch/touch.html

Neuroscience for Kids, from Eric H. Chudler, University of Washington in Seattle http://faculty.washington.edu/chudler/neurok.html

What Does Handedness Have to Do with Brain Lateralization?, from M. K. Holder, Indiana University Bloomington http://www.indiana.edu/~primate/brain.html

Name ____________________________ Date _________________________

Lesson 8: Reaction Time

Reaction Time Worksheet

Find a partner to work with. Before discussing with your partner, make a prediction about what side of their body is their dominant side (left or right)?

Hypothesis: (Predict: What is your answer to the question and why do you think that is the answer?) Discuss your predictions with your partner aloud.

Test 1- Eye Test: Have your partner extend their arms in front of their body. Have them make a triangle shape using their fore fingers and thumbs. Have them bring their hands together, making the triangle smaller (about the size of a coin is good). Find a small object in the room and focus on it through the hole in their hands (using both eyes). Have them try closing just their left eye and then just their right, if your view of the object changed when they closed their left eye mark down 'left' under test 1, if it changed when they closed their right eye mark down 'right'.

Test 2- Eye Test: Give your partner a blank paper and roll it into a tube and ask them to look at a distant object through it. *Which eye do they use to look through the tube?* Record the result in your data table. Mark left eye or right eye in the chart below.

Eye Tests	Test 1	Test 2
Did they use their left eye or right eye?		

Test 3- Ear Test- Have your partner 'pretend' to answer a phone. *Which ear do they put the fake/imaginary phone up to?* Record the result in your data table in the "Ear" column, under your partner's name.

Ear Tests	Test 3
Did they use their left ear or right ear?	

Test 4- Leg/Foot Test- Have your partner pretend there is an imaginary ball on the ground and kick it. Which foot do they use?

Test 5- Leg/Foot Test: Place a coin/or object on the floor directly in front of your partner. Ask them to step onto the coin. *Which foot is used to step on the coin?* Record the result in your data table in the "Foot" row, under your partner's name.

Leg/Foot Tests	Test 4	Test 5
Did they use their left leg/foot or right leg/foot?		

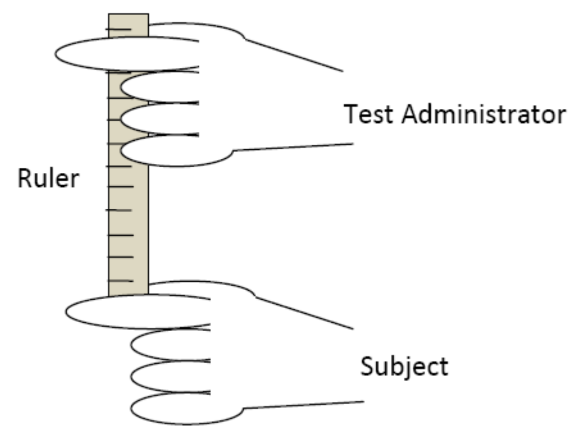
Test 6- Hand/Arm Test: Ask your partner to write their name on a piece of paper. *Which hand do they write their name with?* Record the result (writing either "Right" or "Left") in your data table in the column labeled "Test 3".

Hand/Arm Test	Test 3
Did they use their left hand/arm or right hand/arm?	

Test 7- Hand/Eye Test- Action Reaction Test

- Hold a 12 inch ruler near the end with the highest number and let it hang down. Zero inches should be pointed to the ground. Have your partner put his/her dominant hand at the bottom of the ruler, not touching it, and be ready to grab the ruler when it drops.

- Tell your partner that you will drop the ruler sometime in the next five seconds with no countdown warning and that s/he is to try to catch the ruler as fast as s/he can after you drop it. See diagram ➔



- Record in the data table the level on the ruler (centimeters or inches) at which your partner catches it.

- Repeat this test with the same subject for a total of three times.

- Vary the time of dropping within the five-second "drop-zone" so the subject cannot guess when you will drop the ruler.

- Now try a "countdown" case: Conduct the same test with the addition of a countdown warning. Tell your partner that you will drop the ruler at the count of three and say: 1… 2… 3 and drop it when you say 3.

- Record in the data table the point on the ruler where the partner caught it for this trial. Repeat this test with a countdown with the same partner for a total of three times.

	Dominant Hand		**Non-Dominant Hand**	
Trial #	**Test A** **No Countdown**	**Test B** **Countdown**	**Test C** **No Countdown**	**Test D** **Countdown**
1				
2				
3				
Average				

1. Which method resulted in the fastest reaction time?
2. Which method resulted in the slowest reaction time?
3. Why do you think those were your fastest and slowest reaction times?

Sport Science

Lesson 9- Bounce & Collision

Ages 15-19

Overview

Students examine how different balls react when colliding with different surfaces, giving plenty of opportunity for them to see the difference between elastic and inelastic collisions, learn how to calculate momentum, and understand the principle of conservation of momentum.

Sports engineering is becoming a popular specialty field of study. Some engineers dedicate their research to understanding collisions between balls and bats; others study the effects of a golf ball colliding with the head of a golf club. Mechanical engineers consider momentum and collisions when designing vehicles. Learning how the human body and equipment interacts with the ball during impact or how the human body interacts with the inside of a car during a crash, helps engineers design better sports equipment and safer vehicles.

Learning Objectives

1. Students will understand that momentum depends on both mass and velocity.
2. Students will recognize that difference surfaces and materials promote different types of collisions.
3. Students will collect data to solve problems.

Suggested Timeframe

45-60 minutes

Materials Required: (Each team/group of 2-4 students need)

- 3 Different Types of Balls (Suggestions: Ping Pong Ball, tennis ball, racquetball, golf ball, baseball, super ball, clay, billiards ball)
- 3 different bouncing surfaces (Suggestions: tile floor, linoleum floor, carpeted floor, sidewalk, etc.)
- 1 Dry Erase Protective Sleeve for each student
- 1 Thin Expo Marker w/Dry Eraser attached for each student
- 1 Bounce & Collision Worksheet
  Students can place their worksheet inside the protective sleeve and use the dry erase marker to do their work.

(For the Entire Class to Share)

- Gram Scale

Assessment

- Pre-Activity Assessment
- Activity Embedded Assessment
- Post-Activity Assessment

Introduction/Initiation

“Momentum can be thought of as 'mass in motion' and is given by the expression:

Momentum = mass x velocity

*The amount of momentum an object has depends both on its **mass** and **how fast it is going**. For example, a heavier object going the same speed as a lighter object would have greater momentum. Sometimes when moving objects collide into each other, momentum can be transferred from one object to another. There are two types of collisions that relate to momentum: **elastic and inelastic**.*

An ***elastic collision*** *follows the Law of Conservation of Momentum, which states "the total amount of momentum before a collision is equal to the total amount of momentum after a collision."*

An elastic collision example might involve a super-bouncy ball; if you were to drop it, it would bounce all the way back up to the original height from which it was dropped. Another elastic collision example may be observed in a game of pool. Watch a moving cue ball hit a resting pool ball. At impact, the cue ball stops, but transfers all of its momentum to the other ball, resulting in the hit ball rolling with the initial speed of the cue ball.

In an ***inelastic collision****, the total momentum of the system is conserved, but the total kinetic energy of the system is not conserved.*

An inelastic collision example might involve a dropped ball of clay. It demonstrates an extremely inelastic collision. It does not bounce at all and loses its kinetic energy. Instead, all the energy goes into deforming the ball into a flat blob.

Many sports incorporate collisions and momentum as part of game play. Can you think of some?

Certain sports rely primarily on elastic collisions that conserve momentum, such as pool or billiards, while others use inelastic collisions to make the game more challenging.

What would happen if a baseball and a bat had an elastic collision like a golf ball and club?

(Answer: There would be a lot more home runs during a game!) Another way to understand collisions is through Newton's 3rd Law, which tells us that "for every action, there is an equal and opposite reaction". Understanding Newton's 3rd Law, momentum and elastic and inelastic collisions provides a new understanding of our physical world that is full of motion and collisions.

Procedure

Before the Activity

1. Gather materials and give students a copy of the Bounce & Collision Worksheet, a protective sleeve, 1 dry erase marker
2. Give each team: 3 different types of balls, 1 Thin Expo Marker, 1 Bounce & Collision Worksheet & have ready 1 gram scale for the entire class

With the Students

1. Determine the mass in kilograms of each ball and record it on the data sheet.
2. Drop each ball from a distance of 1 meter onto the surface and record how high it bounces in meters (Example: .46 meters).
3. Note whether the ball and surface showed more of an elastic or inelastic collision.
    - If the ball bounces up more than .5 meter then, it is more elastic.
    - If it bounces up less than .5 meter, then it is more inelastic.
4. Repeat steps 1, 2 and 3 for the two other surfaces.
5. Calculate the momentum for each ball at the point that it bounces, and record on the worksheet. Do one example calculation as a class.
    - Note: The momentum calculation is independent of the bouncing surface, so it only needs to be calculated once for each ball.
    - Equation: **Momentum = mass x velocity**

Use the mass determined in step 1. In this example, use .05 kilograms for the mass. Next, determine the velocity of the object when it hits the ground. Velocity of a falling object can be described as:

$$V = \sqrt{2gh}$$

where g is gravity (9.81 m/s2) and h is height (1 m).
Momentum = .05 kilograms x 4.43 meters/second = .222 kg•m/s.

Note: All the balls will have the same velocity because any object dropped from the same height will fall at the same constant rate due to gravity. **So, for this activity, the velocity is: 4.43 m/s.**

6. Once the class is finished with the worksheets, discuss which balls had the best elastic collisions on each surface. Finally, ask the students if they think elastic collisions are more determined by the surface or the momentum.

Assessment

Pre-Activity Assessment

Brainstorming: In small groups, have the students engage in open discussion. Remind students that no idea or suggestion is "silly." All ideas should be respectfully heard. Ask the students:

- What are sports examples of transfer (and conservation) of momentum (Possible answers: Hitting a baseball with a bat, hitting the cue ball with a pool stick, the cue ball bouncing off another ball, striking a golf ball with a club or driver, or hitting a tennis ball with a racquet).

Activity Embedded Assessment

Voting: Ask the students to vote to rank the sports (named above) from those having the greatest momentum to those having the least momentum. While the students will have to use their own judgment, remind them that momentum depends equally on mass and velocity.

Post-Activity Assessment

Challenge Problem Solving: Present the class with the following problems and ask the students to calculate which case has the greater momentum.

- *Case 1:* A big-time slugger hits a 0.14 kilogram (5 ounce) baseball 45 meters/sec (100 mph). (Answer: Momentum = mass x velocity = .14 kg x 45 m/s = 6.3 kg•m/s.)
- *Case 2:* Uncle Marcus knocks down four pins at the Bowl-a-Rena by rolling a 7.3 kilogram (16 pound) ball 4.5 meters/sec (10 mph). (Answer: Momentum = mass x velocity = 7.3 kg x 4.5 m/s = 32.9 kg•m/s.)
- *Solution:* Uncle Marcus gave the bowling ball much more momentum.

Safety Issues

Be sure the students do not use the balls as projectiles.

Activity Extensions

Students could investigate the materials used to make balls as a way to better understand why they bounce the way they do. For example, if you cut open a golf ball, you will find a mass of rubber bands wound around a core that is also usually rubber. All that rubber (and the hard plastic cover) explains its bounciness. A baseball has a similar construction, but with very different materials. A baseball's inside is a mass of yarn wound around a cork core, and its cover material is leather. These materials make for a less bouncy ball. (Note: safety precautions should be taken when opening these balls and should be done under adult supervision.)

Activity Scaling
For lower grades, leave out the part where the students calculate momentum in the activity and focus more on elastic and inelastic collisions. Students should still understand the concept of momentum without actually calculating it. As a class, work the simpler examples in the Assessment section on the board, or have the students complete them individually or with a calculator.

For upper grades, calculate the momentum in the activity as an individual exercise. Have the students write out their steps when solving the mathematical equations. Assign the students to work the problems in the Assessment section individually.

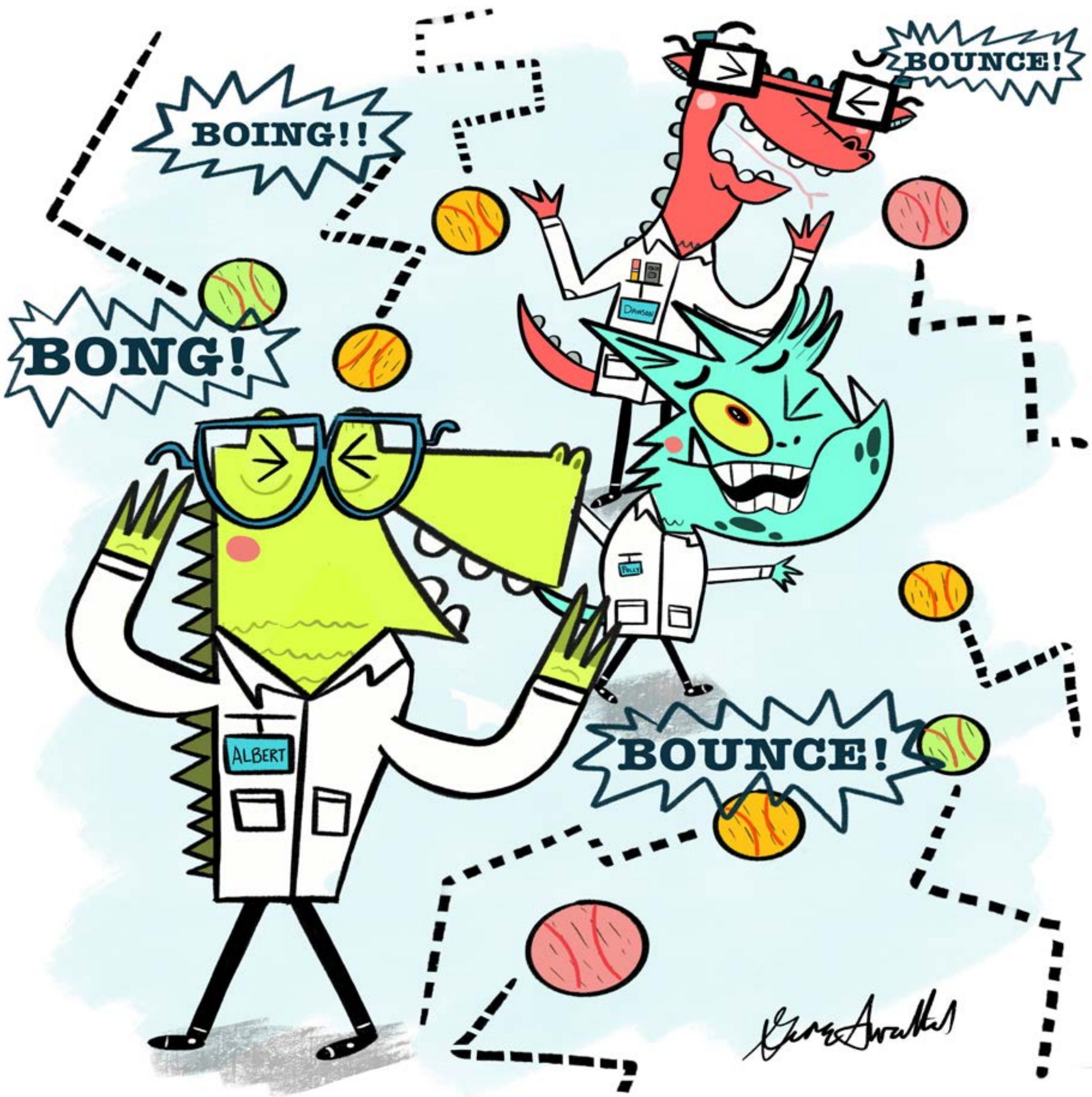
Additional Multimedia
Momentum: http://www.physicsclassroom.com/Class/momentum/momtoc.html

Momentum and energy loss of balls colliding against different surfaces:
http://www.iit.edu/~smile/ph8709.html

Science of Baseball, The Exploratorium: http://www.exploratorium.edu/baseball/index.html

Science of Baseball, The Exploratorium: http://www.exploratorium.edu/baseball/howfar7.html

Science of Baseball, The Exploratorium: http://www.exploratorium.edu/baseball/howfar5.html



Name ______________________________ Date ___________________________

Lesson 9: Bounce & Collision

<u>Bounce & Collision Worksheet</u>

Ball Types:
Ball 1: __________________________________
Ball 2: __________________________________
Ball 3: __________________________________

Surface Types:
Surface 1: ___________________________
Surface 2: ___________________________
Surface 3: ___________________________

Record your data and calculations in the table below.

Ball	Surface	Bounce Height	Elasatic? Or Inelastic?	Mass (m)	Velocity (m/s)	Momentum (kg x m)/s
1	1					
2	1					
3	1					
1	2					
2	2					
3	2					
1	3					
2	3					
3	3					

Equations:

Falling Object Velocity = V = $\sqrt{2gh}$

Where g is gravity (9.81 meters per second and h is height (meters)

Momentum = mass x velocity