National Aeronautics and Space Administration

STEMonstrations

Education in Action on the International Space Station

Classroom Connections

Newton's Second Law

For more STEMonstrations and Classroom Connections, visit www.nasa.gov/stemonstation.

Air Powered Mass: F=ma

Teacher Background

Grade Level: **6th-8th**

Suggested Time: **90 Minutes**

Inquiry Activity (10 minutes); STEMonstration Video and discussion (5 minutes); Student Activity (35 minutes); Students generate adaptations and retest (25 minutes); Final Discussion / Sharing results (15 minutes)

Next Generation Science Standards (NGSS):

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

Disciplinary Core Ideas: *PS2.A: Forces and Motion – The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.*

Crosscutting Concepts: *Stability and Change – Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.*

Science and Engineering Practices: *Planning and carrying out investigations – Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.*

Background

Newton's Second Law of Motion plays an important role in space exploration – it gets our rockets off the ground! This law relates force, mass, and acceleration and is often written as the equation F=ma (F=force, m=mass, and a=acceleration). This equation tells us that an object with more mass requires a larger force to accelerate than an object with less mass. That means a rocket with a lot of mass needs a stronger force to help it accelerate and get off the ground than a rocket with a smaller mass.

Objective

Following this activity, students will be able to:

- Explain Newton's Second Law of Motion and the relationship among force, mass, and acceleration.

Students will test how an equal force impacts an object's acceleration as its mass increases. They will make a paper car that uses wind power (air pump) to propel forward. The car will ride along a track made from straws to simulate motion in one dimension. They will repeat these steps for multiple trials while adding mass each time. By collecting and recording data, students should notice a trend, and use their data to prove Newton's Second Law of Motion. Extensions include making adaptations to the car, or even generating an entirely new design, while comparing their results to the first design.

Inquiry Discussion

Start this lesson by letting students explore Newton's Second Law through inquiry. Provide students with objects of varying masses, and direct them to their Inquiry Activity worksheet (page 4) for directions. Use the following questions to help guide discussions after students have completed the inquiry activity.

1. When you used the tape measure to reel in objects of different mass, what did you observe?
2. How does mass affect the change of motion of an object when it is pushed/pulled?

STEMonstration Video

Show the STEMonstration video: Newton's Second Law. This video is available at www.nasa.gov/STEMonstrations.

Post-Video Discussion

Following the video, ask the students to reflect upon how the demo might look when performed on Earth. In the STEMonstration video, you see NASA Astronaut Randy Bresnik applying the same force to three different objects of varying mass: a stick of lip balm, an Orion spacecraft model, and a large cargo transfer bag (CTB).

Were you able to see how the objects accelerated differently? This difference is due the equation associated with Newton's Second Law of Motion, shown below.

Force = mass x acceleration (F=ma)

Discuss how this compares to their inquiry activity. What did they observe?

Materials Per Group

Inquiry Activity

- Safety googles
- Inquiry Activity Sheet (page 4)
- Tape measure
- Three or more items of varying mass

Student Activity

- Safety goggles
- Student Activity Sheets (pages 5-6)
- Foldable car cutout (page 7)
- Assortment of materials to make adaptations to the car (items such as cardstock, cardboard, foil, paper, etc.)
- 4oz paper or plastic drinking cup
- 15 non-flexible drinking straws (each cut in half)
- Balloon air pump
- Mass scale
- Scissors
- Tape
- Meter stick
- 15 pennies (or flat washers weighing approximately 2.5g each)

Procedure

1. Students will investigate the relationship between force, mass, and acceleration by using a balloon pump to propel a car capable of holding multiple pennies or washers down a track made out of straws.
2. Students can make their own car or the teacher may print the foldable template onto cardstock to reduce time.
3. Distribute supplies to students (recommend students work in groups of two to four students).
4. As an extension, students can alter the design of the initial car entirely or make adaptations to enhance the performance of the vehicle. Have students share their designs and explain why they were or were not effective.

NOTE: This lesson was adapted from NASA's Mass vs. Weight Educator Guide found at https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Mass_vs_Weight.html

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Name: ______________________________ **Class Period**: ______________

Explore

1. Put on your safety goggles.
2. Extend your tape measure to 2 meters (approximately 79 inches), and lock it into place.
3. Tape an object to the end of the tape measure.
4. Release the lock, and record your observations.
5. Repeat steps 2-4 for two additional objects.

	Observations
Object 1:	
Object 2:	
Object 3:	

Air Powered Mass: F=ma

Student Activity

Group Members: ______________________ ______________________

______________________ ______________________

Think About It:

In this activity, you will build a car and move it down a "track" of straws using an air pump. If you increase the mass of the car, how will it impact its acceleration? How will it affect the distance the car traveled?

Procedure

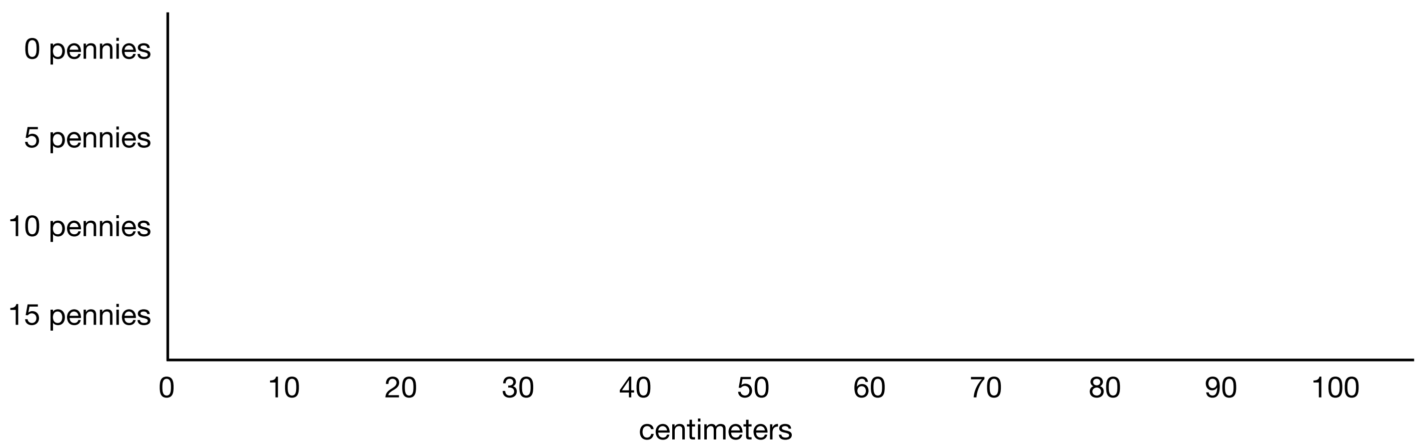
1. Practice safety. Wear your goggles, and stay alert.
2. Construct the car using the provided template.
3. Cut 15 straws in half to make 30 shorter straw pieces.
4. Place a meter stick on a smooth floor or tabletop. Put one straw next to the 0-centimeter mark of the meter stick. Place the second straw parallel to the first at the 2-centimeter mark. Continue placing all the other straws 2 centimeters apart. Be sure the straws are not touching the meter stick. The straws should be parallel to each other like the wooden ties of railroad tracks.
5. Set the car on the straws with the back of the car even with the 0-centimeter straw.
6. Carefully place an empty cup on top of the shaded circle inside the box of the car. Measure the mass of the car and empty cup. Record the mass on your Student Data Sheet
7. Aim the nozzle of the balloon pump straight at the target on the back of the car. Shoot a blast of air at the car and observe what happens. Reset the straws and car and propel it again several times until the car always moves the same distance every time.
8. Begin the experiment by resetting the straws and car. Propel the car with the balloon pump and measure how far the car traveled. Record the distance on the data sheet. Record data for four trials and record the average distance the car traveled.
9. Reset the straws and car but place five pennies into the cup. Propel the car and measure how far it goes with the extra mass. Record your data.
10. Repeat experiment two more times with 10 and then 15 pennies.
11. Record and graph your data for each test on your Student Data Sheet.

Group Members: ______________________ ______________________

______________________ ______________________

Items	Total Mass (g)	Distance Car Traveled (cm)				
		Test 1	Test 2	Test 3	Test 4	Average
Car + Cup +0 pennies						
Car + Cup +5 pennies						
Car + Cup +10 pennies						
Car + Cup +15 pennies						

Plot a bar graph depicting the average distance of the four tests for each mass:



Analyze results

1. Explain the effect mass has on distance traveled. Does your data support Newton's Second Law of Motion?

2. Were your initial predictions in "Think About It" correct? Why or why not?

Extension Questions

1. What adaptations could be made to the car to improve upon its design?
   - Design and implement an adaptation using additional materials provided by your instructor.
   - Rerun your procedures using your new design. What differences did the new design have on your results?

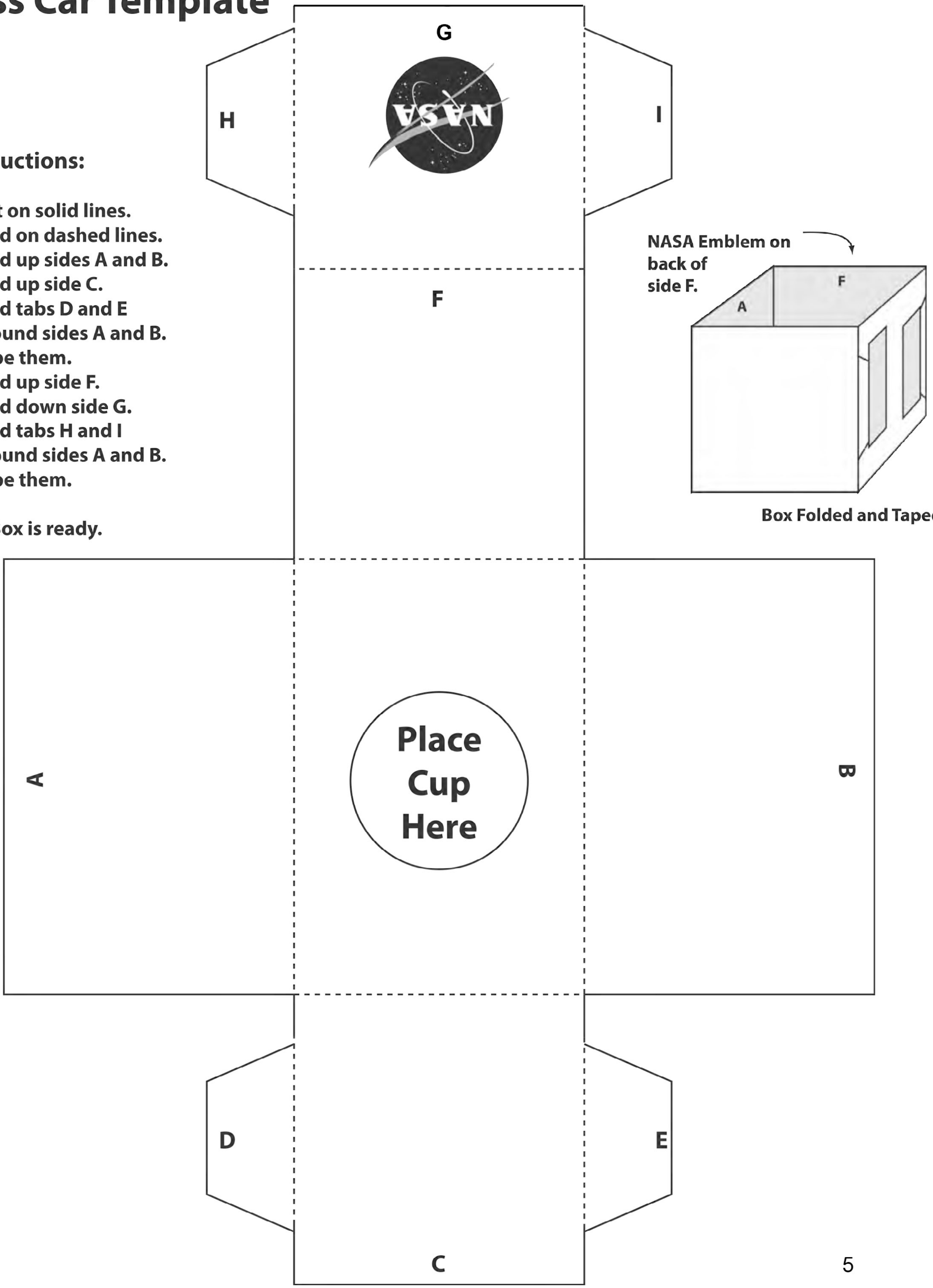
2. How does Newton's Second Law of Motion affect astronauts aboard the International Space Station?

Mass Car Template

Instructions:

1. Cut on solid lines.
2. Fold on dashed lines.
3. Fold up sides A and B.
4. Fold up side C.
5. Fold tabs D and E around sides A and B. Tape them.
6. Fold up side F.
7. Fold down side G.
8. Fold tabs H and I around sides A and B. Tape them.

The Box is ready.



NASA Emblem on back of side F.

Box Folded and Taped

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