# Exploring Design Solutions and Motion

## Companion Lesson to X-STEM All Access Episode "Life Beyond Our World"

| Grade/ Grade Band 6-12 | **Topic:** Physics | |
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**Brief Lesson Description**: Spacecraft Engineer Bobak Ferdowsi explains how NASA makes the journey to Mars. The first thing you need is a rocket. Students plan investigations to understand motion. They will design, test, and revise gliding devices as they discover the impact of force and mass on objects in motion.

**Performance Expectation(s):**
**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.
**MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

**Specific Learning Outcomes:**
Students will demonstrate Newton's 3rd law of motion.
Students will use engineering design to build a two-stage rocket that will travel 2.5 meters.

**Narrative / Background Information**

**Prior Student Knowledge:**
Students can explain Newton's laws of motion.

| Science & Engineering Practices: | Disciplinary Core Ideas: | Crosscutting Concepts: |
|---|---|---|
| **Asking Questions and Defining Problems.** Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to support a claim. (MS-PS2-2)<br>**Analyzing and Interpreting Data.** Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3) | **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. (MS-PS2-2)<br>**ETS1.B: Developing Possible Solutions.** Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.(MS-ETS1-3) | **Cause and Effect.** Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ETS2-3) |

**Possible Preconceptions/Misconceptions:**
Many students believe that all forces must be equal, Newton's third law is applied when the forces are paired.

**LESSON PLAN – 5-E Model**

**ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:**
Prior to the lesson gather the following materials:
Assortment of balloons
Modeling Balloons (long balloons for making animals)
Straws
Binder Clips
Paper towel tubes
Fishing line
tape

Give students the following: assortment of balloons, a straw, 6 strips of tape, 3 meters of fishing line, and a meter stick. Tell students to use the materials to create a model rocket that will travel at least 1 meter. Ask them to sketch their design in advance of building it. After the students build their rockets, they will test to see how far it travels.

**EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:**
Discuss with students how the rocket performed during the tests. Ask the following questions to prompt discussion: how far did your rocket travel, which features in the design of the rocket helped it to travel, which features hindered the rocket's flight, what changes or additions would you make to the design to improve it?

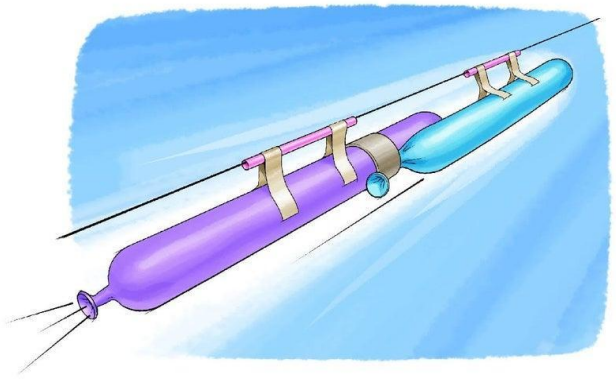
Now view Life Beyond Our World featuring Bobak Ferdowsi. Students should record notes about how Bobak Ferdowsi designs rockets.

**EXPLAIN: Concepts Explained and Vocabulary Defined:**
Explain to students that according to Newton's third law of motion, for every action there is an equal and opposite reaction, means that the straw in the balloon rocket is pushed forward along the fishing line as the air is expelled out of the balloon. The friction between the fishing line and the straw acts opposite the direction of motion of the balloon rocket. According to Newton's second law, F = ma, the rocket balloon's acceleration depends on the mass and the sum of the forces acting on it. Adding a second balloon to the rocket increases the amount of energy used to propel the rocket forward.
**Vocabulary:**
**Newton's third law of motion-** for every action there is an equal and opposite reaction.

**ELABORATE: Applications and Extensions:**
Prior to starting the elaboration section of this lesson, you will need to gather the following materials (per team):
Student teams will need the following materials:

- Modeling balloons (2)
- Binder clips (2)
- Straws (2)
- ½ - ¾ inch cardboard ring
- 4 strips of tape
- Fishing line (from the engage stage)

Explain to students that to assemble the 2-stage balloon rocket they will need to delay the expulsion of air from the main balloon. Ask students to plan out their designs focusing their attention on how they will delay the release of air from the main rocket (use the cardboard ring to connect the two balloons such that when the first balloon deflates it provides space for the second balloon to open and expel air), how to ensure the rocket stays straight (don't inflate balloon more than ¾ full).
It can be tricky and frustrating to construct the rocket. Consider sharing the following image from a 2017 Scientific American article:



Once students have assembled their balloon rockets, they will test to see how far it can travel. They should make modifications and record them and the results. Bring the class together for a discussion. Use the following questions to prompt the discussion:

- What changes made the biggest impact on how far the rocket traveled?
- Which changes did not make a difference on how far the rocket traveled?
- What was surprising about your rocket?
- What do you think would happen if there was a third stage/balloon?

**EVALUATE:**

**Formative Monitoring (Questioning / Discussion):** The design plans for the rockets and student responses to the discussion in the lesson.

**Summative Assessment (Quiz / Project / Report):** Students write a report comparing the performance of their single stage rocket to their two-stage rocket and explain how Newtons Laws of Motions are exhibited.

**Elaborate Further / Reflect: Enrichment:** Students explore changing the direction of the travel from horizontal to vertical. How high will the rocket go? What changes need to be made to the rocket to propel it vertical and why?

**SOCIAL EMOTIONAL LEARNING ACTIVITY**

**CASEL Competency: Responsible Decision Making**
Responsible decision-making is the ability to make caring and constructive choices about one's personal behavior and social interactions across diverse situations.
In this activity, students will be strengthening their creative thinking and decision-making skills. Tell students they are stranded on a desert

island. They may only choose 3 of the following objects to survive:

- A Swiss army knife
- A fishing net
- A bag of fruit and vegetable seeds
- A 100 ft rope
- A large bucket
- 2 gallons of kerosene
- A flashlight
- Sunscreen
- A first aid kit
- A waterproof bed sheet
- A wool blanket

Give students 2-5 minutes to write out which 3 items they would select and why. Then ask students to select a partner. Next, students should compare the items they selected and the reasons why, before looking for another pair to partner with. This team of four should share the items they selected and discuss their chances for survival. Lead a class discussion asking students how they decided to create the partnerships and why they think their team will survive. Consider asking students how the items they selected play to their strengths, or did they consider their weaknesses when making the decisions to partner with classmates?

**INTERDISCIPLINARY CONNECTIONS/IDEAS**

With this lesson students are writing a report as well as creating their own diagrams and models. RST.6-8.7 *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually*

**Materials Required for This Lesson/Activity**

| Quantity | Description |
|---|---|
| Per team | 1 balloon (student choice) |
| Per team | 2 modeling balloons |
| Per team | 4 straws |
| Per team | 2 binder clips |
| Per team | One inch cardboard ring (cut from paper towel tube) |
| Per team | Scissors |
| | Tape |
| Per team | Meter Stick/ measuring tape |
| Per class | 1 spool of Fishing line |

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