Description In this lesson, learners use stomp launchers to test launch angles and trajectories. Learners will track data collected by their team and use it to determine the optimal launch angle and height to get their rockets through a suspended target.		
Grade Levels 4-12	**The Tech Challenge Connections** This lesson can help Tech Challenge teams build skills that aid in crafting their solutions, such as: • Experiment with launch angle and height to successfully launch an item through a target.	**Objectives** Learners will: • Explore factors that affect the trajectory height and distance, including force and launch angle. • Analyze and compare data
Duration 75 minutes **Tech Tips** Data Collection Sharing Solutions		**Standards Connections** • *4-MD-6* Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure. • *3-5-ETS1-2* Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem. • *3-5-ETS-1-3* Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Materials

Four launchers for a class of 30 (working in teams of 2-4)

- **Buy stomp launchers**

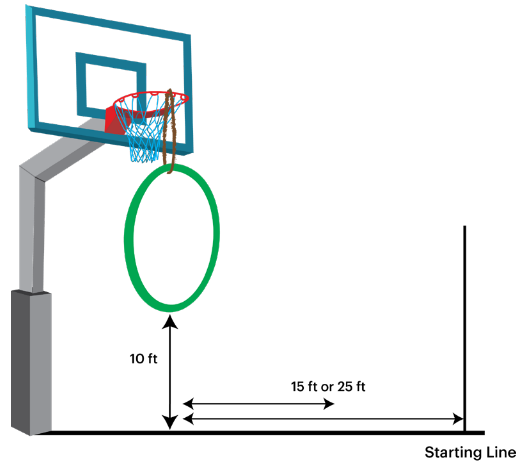
OR

- **Build stomp launchers (materials cost: under $5 per launcher)**
  - Four ½-in. diameter PVC pipes (approx. 18-24 in.)
  - Four ½-in. diameter plastic tubes (approx. 4 ft.)
  - Duct tape (or masking tape)
  - Four 2-liter plastic bottles (these will last for approx. 30-40 stomps, then may need to be replaced)
  - 4 ½ sheets of copy paper
  - 4 large paper clips, metal washers, or nuts (to act as weights for the string)
  - Meter sticks for measuring launch height
  - 4 protractors
  - Four 1-ft. lengths of thick string (kite string or twine)
- Aim High! Data Collection worksheet (1 per student)
- 15 half-sheets of copy paper for paper rockets. See Aim High! Stomp Launcher and Paper Rocket Instructions.

Test Rig

Four Test Areas for a class of 30 (working in teams of 2-4)

- Hula hoop (suspended 10 ft. in the air) hung 15 ft. from "launching line" for the first challenge
  OR A simple Test Rig "hoop" can be built using two pool noodles taped together with duct tape
- Rope or strong string (for suspending the hoop)
- Measuring tape (to measure the distance)
- Chalk or string to mark the starting line
- Stomp launcher



Prep and Set Up

- Collect and sort materials.
- Set up Test Rigs*.
- Build launchers and paper rockets. See Aim High! Stomp Launcher and Paper Rocket Instructions.
- Practice launching paper rockets to gain familiarity with the materials and anticipate questions.

*We recommend having four Test Rigs (stomp launcher, launch line, and hoop target) for a group of 30 students. This activity is best done in a gymnasium or outdoor area.

Lesson

1. Introduce challenge 1 (5 minutes)
   a. Put students into groups and demonstrate how to use the stomp launcher.
   b. Note: This challenge focuses on trajectory angles. If you are covering a related real-world topic, you can use that to frame the challenge. Some topics may include catapults, the motion of aircraft, space exploration, or the science of sports (path of a thrown or hit ball).

Challenge 1

Determine the optimal angle for launching an object through a hoop suspended 10 ft. in the air and 15 ft. away.

Criteria

- Rocket must be launched from the launch line.
- Rocket must travel through the hoop target 15 ft. away.

Constraints

- Rocket can only be launched with the stomp launcher.
- Learners may only use one foot on the stomp launcher.
- Rocket must travel through the hoop without touching it.

2. Practice and familiarize (5 minutes)
   a. Allow teams to practice launching the rockets without measuring the angles to get a feel for how the launchers behave.
   b. Demonstrate how to measure the launch angle using the attached protractor, which measures the distance the rocket travels.
   c. Have students practice measuring the horizontal distance the rocket travels and the launch angle, and record it on the data collection sheet under "Launch Distance."

3. Launch and record (15 minutes)
   a. As learners test, ask facilitative questions:
      i. *How can you alter the angle to get the rocket closer to the target?*
      ii. *What did you notice about the launch angle and how far the rocket goes?*

4. Share out (10 minutes)
   a. Gather teams together to discuss their results and analyze their data.
   b. Provide learners with a method to record their results for everyone to see. You can use a Google Sheet or whiteboard. See the sample below.
   c. Sample Class Data Chart

Team Name	Launch Angle	Launch Distance	Observations

   d. Possible questions:
      i. *What effect did changing the launch angle have on the trajectory?*
      ii. *Which launch angle was most successful?*
      iii. *Does the launch angle impact the distance?*
      iv. *Is our data consistent?*
      v. *What changes did you make to address these inconsistencies?*
   e. For more ideas, see Tech Tip: Sharing Solutions.

5. Introduce Challenge 2 (5 minutes)
   a. Suggested wording: *Now that you're familiar with these ideas/concepts, we are going to adjust the criteria.*

Challenge 2
Determine the optimal angle for launching an object through a hoop suspended 10 ft. in the air and 25 ft. away.

Criteria
- Rocket must be launched from the launch line.
- Rocket must travel through the hula hoop target 15 ft. away.

Constraints
- Only the materials provided may be used.
- Learners may only use one foot on the stomp launcher.
- Rocket must travel through the hoop without touching it.

6. Launch and record (10 minutes)
   a. Allow time for groups to record their measurements on their data collection sheet and Class Data Chart.

7. Share out (15 minutes).
   a. Gather the class together to do a final launch and share their findings.
   b. Suggested wording: *What launch height worked the best? What are some other heights you tried that didn't work? How did changing the launch height affect the trajectory of your rocket?*
   c. Use the Class Data Chart from the whiteboard or Google Sheet to graph launch angle vs. distance.
      i. Discuss any patterns they see in the graph.
      ii. *Does the launch angle impact the distance the rocket travels?*

Extensions and resources

1. Have learners design features such as a nose cone and fins to increase accuracy and distance. Have a class competition to create the launch that is the most accurate, launches the highest, and/or launches the greatest distance.
2. Use a cell phone to record video of the launches. Play them back in slow motion to analyze the trajectory of the rockets.

Aim High: Directions for Assembly

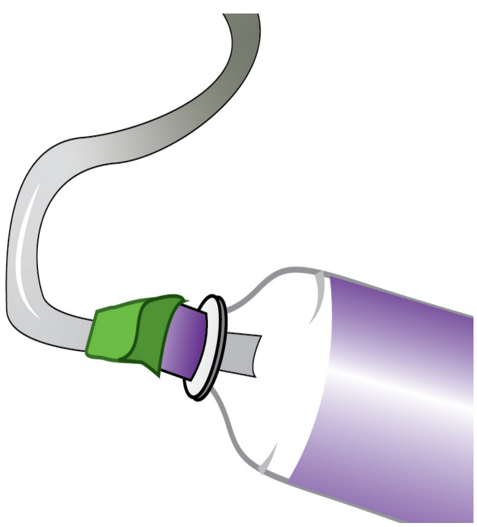
It is recommended that educators assemble the launchers and paper rockets in advance to allow learners more time to attend to the focus of the lesson. Stomp launchers can be purchased or built from simple materials.

Materials Needed to Build a Class Set of 4 Launchers

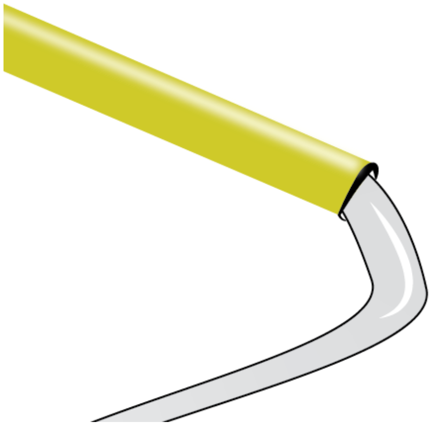
Each launcher costs approx. $5 (PVC & tubing) to build

- Four ½-in. diameter PVC pipes (approx. 18-24 in.)
- Four ½-in. diameter plastic tubes (approx. 4 ft.)
- Duct tape (or masking tape)
- Four 2-Liter plastic bottles (these will last for approx. 30-40 stomps, then may need to be replaced)
- 4 ½ sheets of copy paper
- 4 large paper clips, metal washers, or nuts (to act as weights for the string)
- Meter sticks for measuring launch height
- 4 protractors
- Four 1 ft. lengths of thick string (kite string or twine)

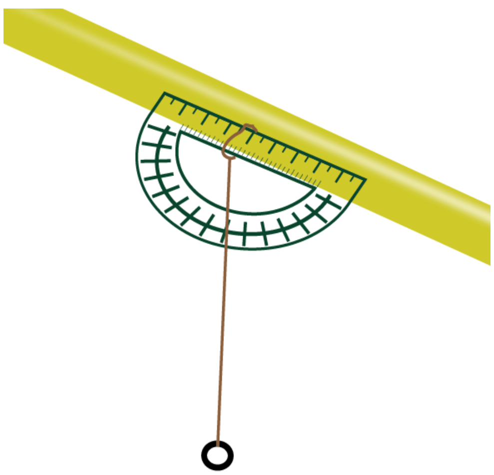
Stomp Launcher



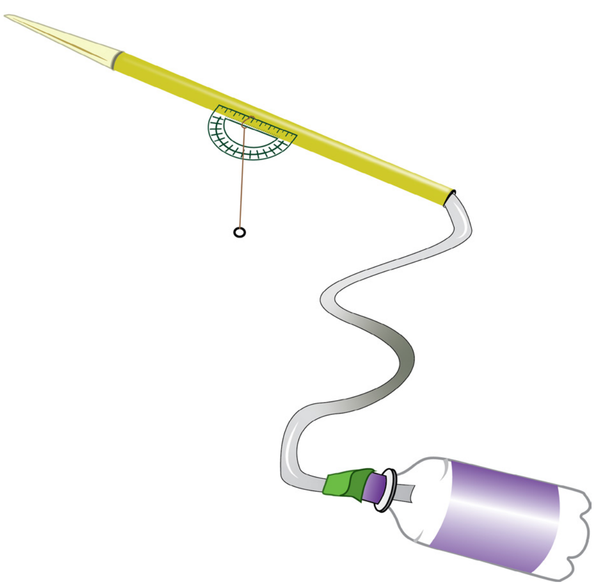
Place one end of the tubing into an empty 2-liter bottle. Using duct tape (or masking tape if held tight), connect the tube to the bottle opening creating an air-tight seal.



Place the other end of the tube into one end of the PVC pipe. It should fit securely. If needed, seal it with tape as well.



Tie a string to the center hole of a protractor and connect the large paper clip (a washer or nut can be substituted) to the other end of the string so that it acts as a weight. Tape the protractor to the center of the PVC pipe and allow the string to hang freely. This will allow learners to measure the launch angle.

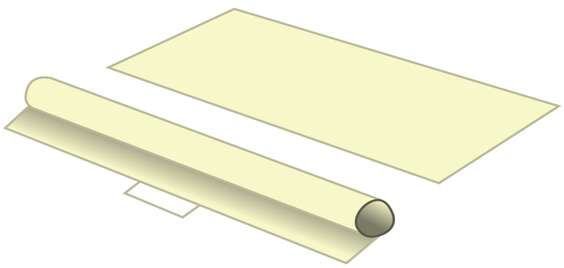


Place the paper rocket (see directions below) on the open end of the pipe, and the bottle on the ground. When the bottle is stomped on, the rocket should propel!

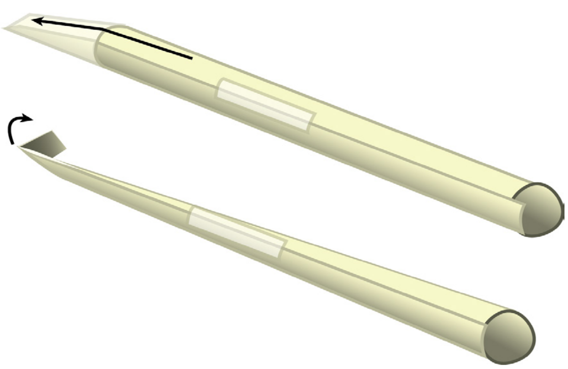
Note: The bottle will need to be re-inflated by wrapping your hand over the open end of the PVC pipe and blowing into your hand between uses. One bottle is good for approximately 30-40 launches. Have extra bottles on hand.

Paper Rocket

Paper rockets are used because they are lightweight. Use of a heavier material may create some difficulty for learners.



Cut an 8 ½ x 11 in. piece of scrap paper in half, creating two 8 ½ x 5 ½ in. pieces. Wrap one of the pieces of paper around the PVC pipe, and tape into a tube shape. The tube should fit snugly but be able to slide over the end of the PVC pipe.



Fold the end of the paper tube and fasten with tape to seal it.

Name/Team ____________________________

Design Challenge 1
Launch Height:

Trial	Launch Angle	Launch Distance	Observations/Notes
Test			
1			
2			
3			
4			
5			

How did changing the angle affect the distance your rocket traveled?

Which launch angle was the most successful?

How did your data/findings compare with the findings of other groups?

Design Challenge 2: Altering the Launch Height
Launch Angle:

Trial	Launch Angle	Launch Distance	Observations/Notes
Test			
1			
2			
3			
4			
5			

What effect (if any) did altering the launch height have on the trajectory of your rocket?

How did your results compare to the other groups' findings?