Mars Pathfinder Egg Drop Challenge

NASA SUMMER OF INNOVATION

UNIT
Engineering—Design Process

GRADE LEVEL
7 – 9

CONNECTION TO CURRICULUM
Engineering and Technology

TEACHER PREPARATION TIME
20 minutes

LESSON TIME NEEDED
45-90 Minutes *Complexity: Moderate*

LESSON THEME

Design, build, and drop your "Pathfinder" from a high place and see if your payload (egg) survives.

OBJECTIVES

Students will

- Demonstrate an understanding of the of challenges of soft landing a spacecraft on Mars
- Design, build, and test their own interplanetary lander

NATIONAL STANDARDS

National Science Education Standards (NSTA)

Science as Inquiry

- Understanding of scientific concepts
- An appreciation of "How we know" what we know in science
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science

Physical Science

- Motions and Forces
- Transfer of Energy

Science in Technology

- Abilities of technological design

ISTE NETS and Performance Indicators for Students

Creativity and Innovation

- Apply existing knowledge to generate new ideas, products, or processes

Critical Thinking, Problem Solving, and Decision Making

- Plan and manage activities to develop a solution or complete a project

Research and Information Fluency

- Plan strategies to guide inquiry
- Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media
- Evaluate and select information sources and digital tools based on the appropriateness to specific tasks
- Process data and report results

Technology Operations and Concepts

- Understand and use technology systems
- Select and use applications effectively and productively
- Troubleshoot systems and applications
- Transfer current knowledge to learning of new technologies

MANAGEMENT

Organize students into small groups. Post the essential questions. Prepare the materials. Show Mars Landers on YouTube.

CONTENT RESEARCH

Mars Pathfinder entered the upper atmosphere of Mars at 7.6 kilometers per second at a 14.2 degree angle (90 degrees would be straight down). It met its peak atmospheric shock, encountering forces 25 times Earth's gravity, at 32 kilometers above the surface. At 10 kilometers above the ground, a parachute deployed at nearly twice the speed of sound (400 meters per second). Rockets inside the back shell fired to further slow the lander's descent. Shortly before landing, a set of airbags inflated to cushion the impact. After a few seconds, the tether attaching the lander to the backshell and parachute severed, and with 90 percent of the fuel expended, the rockets carried the shell and other debris away from the landing area. Then, protected by its airbags, Pathfinder bounced on the Martian surface, as high as a 10-story building, before finally coming to rest after its 8-month journey.
http://www.nasa.gov/mission_pages/mars-pathfinder

MATERIALS per team:

- 1 raw egg or light bulb
- Square yard of tightly woven nylon material
- 5 feet of string
- Paper lunch bag
- Plastic shopping bag
- 2 to 3 balloons
- 2 paper clips
- Three 8.5- by 11-inch sheets of paper
- Masking tape

Materials per whole group:

- Box of pape rclips
- Ladder
- Sensitive scale (e.g., postal scale)

Key Concepts and Terms

Acceleration: Any change in speed or velocity (when an object speeds up, slows down, or changes direction). Acceleration can be described as positive or negative (e.g., speeding up is positive acceleration, slowing down is negative acceleration).

Airbags: Vehicle safety device that consists of a flexible envelope designed to inflate rapidly during a collision to prevent damage to the vehicle.

Atmosphere: All of the gases that surround a planet or star.

Force: Any influence that causes a free body to undergo a change in speed.

Gravity: Force between objects based on their masses and the distance between the objects. The force of gravity of large objects, such as moons and planets, is strong enough to cause objects to be “caught in an orbit” around them. The force of gravity on the Moon is less than the force of gravity on Earth because the Moon has only 1/6 the mass of the Earth.

Mars: Cold desert world that is half the diameter of Earth and has the same amount of dry land. Like Earth, Mars has seasons, polar ice caps, volcanoes, canyon,s and weather, but its atmosphere is too thin for liquid water to exist for long on the surface. There are signs of ancient floods on Mars, but evidence for water now exists mainly in icy soil and thin clouds.

Mars Pathfinder: Free-ranging robotic rover delivered to the Mars planet surface. The scientific objectives include atmospheric entry science, long-range and closeup surface imaging, with the general objective being to characterize the Martian environment for further exploration. In addition to scientific objectives, the Mars Pathfinder mission was also a "proof-of-concept" for various technologies, such as airbag-mediated touchdown and automated obstacle avoidance. The lander and rover operated until communication was lost for unknown reasons. It was supposed to function for 1 month, but lasted for 3 months.

Re-entry: Return of a spacecraft on to a planet through its atmosphere.

Speed: Time it takes an object to travel a certain distance. Speed equals distance divided by time or $s = d / t$.

Velocity: Speed and direction of travel of an object is the object’s velocity. Velocity is similar to speed, but whereas an example of speed would be, “the wind was blowing at 40 miles per hour,” velocity would be expressed as “40 miles per hour from the SE.” Direction becomes important when dealing with navigation of boats, aircraft, wind, and water currents, etc.

LESSON ACTIVITIES

Mars Pathfinder Egg Drop activity:
http://solarsystem.nasa.gov/docs/Egg_Drop_508FC.pdf

Mars pathfinder landing YouTube:
http://www.youtube.com/watch?v=PJLQ2VTuQFY

ADDITIONAL RESOURCES

Lunar Nautics: Designing a mission to live on the Moon:
Lunar Nautics

Educators Guide: Real World Mathematics; Preparing for a soft landing:
http://www.nasa.gov/pdf/324286main_Realworld1.pdf

DISCUSSION QUESTIONS

1. What did you do to measure the motion of flight test models? *Recorded the distance the models fell and the time it took for them to travel this distance. Answers will vary.*
2. Which of the vocabulary terms above best describes the motion of the models? *If you describe how fast an object travels, you are describing speed. If you also include the direction the balls travel, you are describing velocity.*
3. Calculate the speed of your team’s model. *Answers vary. Average speed is calculated by dividing the distance the model fell by the mean drop time.*
4. How does the speed of all flight test models compare? *Depending upon the design of the flight test models, answers may vary. The shape of the models may increase air resistance and slow down the drops.*
Compare the distance the model falls each second as it falls. This represents acceleration due to gravity. When an object is dropped and pulled to Earth’s surface, there is a relationship between the distance *(d)* and time *(t)* the object travels to Earth’s gravity *(g)*. The relationship is given in this equation: ***g = 2 d / t 2*** 6. One Earth gravity (1 *g*) is measured as the acceleration of an object affected only by Earth’s gravity. This acceleration is approximately 9.8 meters/second squared (9.8 m/s^2) or 32 feet/second squared (32 ft/s^2). Ignoring air resistance, the speed of an object falling freely near Earth’s surface increases by 9.8 meters per second every second.

- a. Calculate mean time and average speed for your flight test model.
- b. Calculate the model’s acceleration due to gravity. *Following the formula g = 2 d / t 2*
- c. How close to 9.8 m/s^2 is your calculated value for *g*? *Answers vary. If there is no air resistance and the distance and time are accurately measured, the calculated value for g should be close to 9.8* m/s^2.

5. Was the Mars Pathfinder mission successful? Why or why not? *Answers will vary. From landing until the final data transmission on September 27, 1997, Mars Pathfinder returned 2.3 billion bits of information, including more than 16,500 images from the lander and 550 images from the rover, as well as more than 15 chemical analyses of rocks and soil and extensive data on winds and other materials.*

ASSESSMENT ACTIVITIES

Use the design challenge rubric in soft landings http://www.nasa.gov/pdf/324286main_Realworld1.pdf
Collect data journals.
Create videos of the egg drops. Segment the video into 1-second intervals. What can be learned/observed by watching the segmented intervals?
Answer the essential questions:

- How is the challenge of space exploration driving scientific and technological advancement?
- What affects the speed of a falling object?

ENRICHMENT

In this activity, students tested their creations on home ground. As a follow up, challenge them to research relevant similarities and differences between the Earth, Moon, and Mars and draw conclusions as to how these might affect the design of their lander. *The Moon has no atmosphere. Parachutes would be useless in slowing down landers on the Moon. Mars does have an atmosphere, but it is very thin. Therefore, a descent device that relied solely on a parachute to slow it down would not work nearly as well on Mars as on Earth, unless it were much bigger. This, in turn, adds weight and volume to the spacecraft. Mars has only about one-third of Earth's gravity. Therefore, objects fall more slowly on Mars. Dropping something from a relatively low height on Earth would cause the object to have the same speed on impact.*

Students studying physics will have ample opportunities to take this activity further. They can, for example, study a lander's changing potential and kinetic energies as it falls. They can also study the rate of fall of the lander and compare final velocities, with and without parachutes, while learning about drag. Also noting that the force of gravity on Mars is only 38 percent of that on Earth, they can calculate how high a drop on Mars would result in the same velocity upon impact as a drop from a three-story building on Earth.

Write a news report for July 4, 1997, the day Pathfinder landed on Mars. Research the descent and landing sequence and what scientific data it collected as it descended through the Martian atmosphere. Do the same for the Sojourner rover as it leaves the lander and begins to traverse the Martian landscape. How is it powered, how long will it function, what data will it be sending back to Earth? Research MARS '96, the Russian mission slated to take off in mid-November 1996, but to arrive at Mars after Pathfinder. Report to the class on similarities and differences between the Russian and American missions in terms of the rocket being used and the design of the lander.