Landing a Rover

NASA SUMMER OF INNOVATION

UNIT
Engineering—Exploration

GRADE LEVELS
4 – 6

CONNECTION TO CURRICULUM
Newton's Second Law, Friction, Potential and Kinetic Energy, and Measurement

TEACHER PREPARATION TIME
30 – 60 minutes

LESSON TIME NEEDED
Three 1-hour sessions *Level: Intermediate*

LESSON THEME

The teams' challenge is to design and build a model of a Lunar Transport Rover that will carry equipment and people on the surface of the Moon.

OBJECTIVES

Students will
- Apply the engineering design process
- Design and build a rover that can roll down a ramp
- Design and build a landing pod for this rover
- Meet all engineering design constraints
- Simulate a lunar landing from a significant height (3 to 5 meters)
- Improve their designed system based on testing results

NATIONAL STANDARDS

National Science Education Standards (NSTA)
Science as Inquiry
- Understanding of scientific concepts
- Understanding of the nature of science
- Skills necessary to become independent inquirers about the natural world
- Dispositions to use the skills, abilities, and attitudes associated with science

Common Core State Standards for Mathematics (NCTM)
Geometry
- Draw, construct, and describe geometrical figures and describe the relationships between them
- Solve real-life and mathematical problems involving angle measure, area, surface area, and volume

ISTE NETS and Performance Indicators for Students
Creativity and Innovation
Students:
- Apply existing knowledge to generate new ideas, products, or processes
- Create original works as a means of personal or group expression
- Use models and simulations to explore complex systems and issues
- Identify trends and forecast possibilities

Critical Thinking, Problem Solving, and Decision Making
Students:
- Identify and define authentic problems and significant questions for investigation
- Plan and manage activities to develop a solution or complete a project
- Collect and analyze data to identify solutions and/or make informed decisions
- Use multiple processes and diverse perspectives to explore alternative solutions

MANAGEMENT

Read the challenge sheet and leader notes to become familiar with the activity. Gather the materials ahead of time and set them up in a central location for student access. Determine a location for dropping the designs from heights of 1 to 5 meters. Build a sample lunar rover and landing pod to test as a baseline and encourage students to design a better model.

CONTENT RESEARCH

Friction—To move, rovers need friction between the wheels and ground. To be efficient, rovers need minimal friction between the axle and rover body.

Newton's Second Law—Force = Mass x Acceleration

Potential and kinetic energy—When the rover is at the top of the ramp it possesses stored energy or potential energy. As the wheels spin, the potential energy is changed to motion (kinetic) energy. When the landing pod hits the surface, its motion (kinetic) energy is changed into stored (potential) energy, which gets stored in the shock absorption structures.

Air resistance—Air exerts a force on the landing pod as it falls, slowing it down.

Measurement—Students measure how far their rovers traveled, the various heights from which they drop the landing pod, and the combined mass of the Lunar Transport Rover and the landing pod, which must be less than 300 grams.

Misconceptions:

- The most common misconception of Newton's Second Law is the idea that sustaining motion requires a continued force. Students should have opportunities to investigate the effects of net forces on objects prior or after the challenge. A net force (an unbalanced force) causes an acceleration of an object; the acceleration is in the same direction as the net force. For example, slide a book across a table and watch it slide to a rest position. The book in motion on the table top does not come to a rest position because of the absence of a force; rather it is the presence of a force—that force being the force of friction—that brings the book to a rest position. In the absence of a force of friction, the book would continue in motion with the same speed and direction forever (or at least to the end of the table top).
- Students may have difficulty recognizing the lack of air resistance on the Moon due to the lack of an atmosphere. It is important to compare the Earth and Moon and allow students to research how they might modify their designs for use on the Moon or even other planets like Mars to account for different atmospheric conditions.

MATERIALS

(Rovers and Landing Pods)

- *Corrugated cardboard*
- *General building supplies and tools*
- *2 small plastic people (approx. 2 cm each)*
- *Plastic egg*
- *4 plastic, cardboard, or "Lifesavers" candy wheels*
- *Aluminum foil*
- *Something to use as a ramp (a book would work, but preferably a flat surface that would enable the rover to roll for 50 cm or more)*
- *Bubble wrap*
- *Scale*

LESSON ACTIVITIES

- Introduce the challenge: Tell students how NASA astronauts will need Moon cars—called rovers—to drive across the Moon's surface, carry supplies, help build their outpost, and explore the area. Ask students why a spacecraft that can land gently is important for getting astronauts to and from the Moon safely (scripted in the guide).
- Brainstorm and design: Students should be working in cooperative groups to develop a group design and using individual journals to record their decisions, design sketches, test results, etc.
- Build, test, evaluate, and redesign: build lunar rovers in session one, build the landing pods in session two, and combine models for landing the lunar rover in the landing pod in session three. Test data, solutions, modifications, etc., should all be recorded in their journals individually. Students must meet the engineering design constraints as outlined by the guide.
- Discuss what happened: Ask the students to show each other their lunar rovers and landing pods and talk about how they solved any problems that came up.
- Evaluation: Using the students' journaling, assess their mastery of content, skills, and the engineering design process.

Resource Web Sites:
Best Robotics Resource Web Site:
Grades 3–5 http://aesp.psu.edu/files/soi/BEST%20Activities%203-5.pdf
Grades 5–8 http://userpages.umbc.edu/~hoban/BEST/ePD/activities/6-8.pdf
Mars Rover Video:
http://marsrover.nasa.gov/gallery/video/challenges.html

ADDITIONAL RESOURCES

Mars Rover Mission Pages:
http://marsrovers.nasa.gov

Check out NASA's Exploration Mission Directorate at http://www.nasa.gov/exploration/home/index.html

Destination Tomorrow Video:
http://nasa.ibiblio.org/details.php?videoid=6147&start=0&program=NASA-Destination-Tomorrow

Check out NASA's Moon missions at http://nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html

NASA Images:
http://history.nasa.gov/ap11ann/kippsphotos/apollo.html

DISCUSSION QUESTIONS

- What kinds of Earth vehicles are similar to rovers? *Snowmobiles, tanks, dune buggies, and all-terrain vehicles are similar. They all have good traction, are very stable, have powerful engines, and do not require a roadway.*
- How does the steepness (slope or "rise-over-run") of the ramp affect your design of the rover?
- What changes to the rover design have you made based on performance testing with the ramp? *Answers vary.*
- NASA used a parachute to slow the descent of the Mars rovers onto Mars. Why can we not use a parachute to land a spacecraft on the Moon? *The Moon has no atmosphere so no air resistance exists to slow the landing.*
- They also used a heat shield on the Mars entry spacecraft. Why do we not need one of those on the Moon? *The Moon has no atmosphere; therefore, no air resistance exists to cause heat by friction.*
- How did friction affect your rover? *To be efficient, there needs to be minimal friction between the axle and the axle hole in the cardboard. To move, there needs to be lots of friction between the wheels and the ground.*
- How did the rover use potential and kinetic energy? *Potential energy is energy that is stored. Kinetic energy is the energy of motion. Winding the front wheels increased the amount of potential energy stored by the rubber band. When the wheels spin, this potential energy is turned into kinetic energy, and the axle and wheels turn.*
- What are your ideas for how to protect the rover inside the landing pod? *Answers vary.*
- What was the most challenging aspect of this entire process? *Answers vary.*
- Did you think about the whole process when you were designing the lunar rover? Did you worry about how it would survive the landing as you were building it, or did you not think about that until you were building the landing pod? *Answers vary.*

ASSESSMENT ACTIVITIES

Journaling is a valuable tool for engineers as they prepare and test designs to solve complex problems and meet challenges. Students should record their brainstorming session ideas, labeled and annotated sketches of their prototype designs, test results, modifications to their designs with sketches, photos, and group solutions that allow them to meet the challenge in a journal. They should also record any science, math, engineering, or technology content that is connected to their work or that they used to meet the challenge. The journal should be used as a formative and summative assessment tool.

Designs that meet the challenge should meet the following Engineering Design Constraints:

The lunar rover must meet the following engineering design constraints:

- Carry one plastic egg snugly. The egg may NOT be taped or glued into place. The egg will be what materials are carried in around the Moon.
- Have room for two plastic people. The people do not land with the rover. They will get in the rover on the Moon and drive it around.
- Roll on its own down a ramp with a rise-over-run of 1-over-3 for a distance of approximately 50 cm.
- Survive the “landing.” This means it should be able to roll down the ramp after the landing, and the plastic egg should not have popped open.

The landing pod must meet the following engineering design constraints:

- Safely deliver the lunar rover to the surface from a height given.
- The rover inside the pod, must land RIGHT-SIDE up. The rover must be able to “roll out”, so it must land in the correct orientation with wheels on the surface.
- The landing pod must be reusable. Students must be able to open it, retrieve the lunar rover, and then use the landing pod again.

ENRICHMENT

How high can you go contest: Students drop their landing pods from 1 meter. Eliminate all landing pods that are over 300 grams, do not land upright, have hatches that pop open on impact, are not reusable and/or cannot be opened to allow the rovers to roll down the ramp. Next, raise the height. Continue in this fashion until a winner emerges.

- **Determine the effect of friction:** Instruct students to test their rovers on the ramps a set number of times and measure the distance their rover travels. Then have them minimize friction in the wheel-axle system. For example, they can line the axle holes with a material such as aluminum foil, then retest their rovers. Use the following formula to calculate the percent increase in distance traveled:

$$\text{Percent Increase} = \frac{\textit{(Distance modified rover traveled)} - \textit{(Distance basic rover traveled)}}{\textit{Distance basic rover traveled}} \times 100$$