Rover Landing Design Challenge

Description:
Students explore the concepts of forces and motion as they design protective devices that will enable their 'Egg Rovers' to safely land on a surface after being dropped from a designated height.

Grade Levels: 3-12

Educational Outcomes:
1) Students will learn some basic facts about Mars and the Mars Rover exploratory missions.
2) Students will apply their knowledge of forces, motion to the design of their devices.

Estimated Time: 1 class session (30-40 minutes)

California Science Standards Connections:

Grade 3 - Physical Science:
1. Energy and matter have multiple forms and can be changed from one form to another.

Grade 6 - Physical Science:
3a. Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.

Grade 8 - Physical Science:
2. Unbalanced forces cause changes in velocity.
2 d. Students know how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

Grades 9-12 - Physical Science:
1. Newton's laws predict the motion of most objects.
2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.

All Grades: Investigation and Experimentation: Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.

The Tech Museum Connections:
Exploration Gallery; Labs: Physics of Rollercoasters, Energy at Play, Mars Rover, Robochallenge; Floor Activities: Bobsled DC; IMAX: Space Station, Cosmic Voyage

Materials:
- Newspaper
- Plastic bags
- Foam (all kinds)
- Balloons (1-2 per team)
- Bubble wrap (1 6"x 4" piece per team)
- Packing peanuts (one handful per team)
- Toilet paper/paper towel rolls
- Straws
- Craft sticks
- Masking Tape (10 inches max. per team)
- Rubber bands
- String
- Cardstock/used folders
- Paper clips
- Binder clips
- Scissors
- Raw eggs, double-bagged
- Ziploc bags
- Launch platform (shoebox lid)
- Ladder, chair, countertop for instructor to stand on to reach the required 8 ft. drop height.
- Launch Tarp

Additional material for instructors:
Handi-wipes to have on hand

A. Design Challenge

Scenario:

Exploring new worlds is tricky business, especially if that new world is another planet! One of the most difficult aspects of sending a rover to Mars has been designing a way to land the rover on the planet without completely destroying all of its scientific instruments!

Challenge:

Design and build a landing device for your 'Egg Rover' that will protect it from structural damage when landing on Mars (dropped from a height of 8 feet by the instructor).

Constraints:

1. Base of landing device must fit on launch platform (the lid of a shoe box) and rest in a stable position
2. Egg itself may not be modified in any manner.
3. Devices must be built to allow for quick "unloading" of the 'Egg Rover' for damage assessment.
4. Only provided materials may be used.

Procedure for instructors:

1. Instruct students that they are being presented with a challenge to safely land their 'Egg Rover' onto a planet's surface. They will be working in teams of 2-3 and will have 20 minutes to complete their designs. At the end of the time, they will have the instructor/teacher launch their 'Egg Rovers' with the landing devices that they designed and assess if there was any structural damage upon landing (egg breakage).
2. Present students with the variety of materials. Inform them that they may only use the items provided and that some items are available only in limited quantities.
3. At the end of the design time, assemble student around the launch device (ladder) and team-by-team, launch the rovers and assess for damage.

B. Design Challenge Demonstration and Reflection:

Demonstration: Test devices one team at a time by dropping 'Egg Rovers' from designated height (adjust according to student age level and ability).

Reflection: Have each group of students explain their design strategy. Instructor should ask leading questions to get at the science and thinking behind the designs.

Note: Even if the device doesn't quite work (i.e. the egg broke or was slightly cracked), students should be able to explain their thinking

- The latest Mars exploration rovers, Spirit and Opportunity, were launched by NASA in June and July 2003, respectively. Both landed on Mars in January of 2004.
- It is expected that the spacecraft enter the Martian atmosphere traveling around 7.5km/sec (16,875 mph) and are slowed to about 900 mph by the atmosphere. They must then slow themselves down enough to provide a safe landing (they use a parachute, rocket bursts, and airbags).
- The spacecraft are expected to bounce at least a dozen times upon landing, and roll up to a kilometer before stopping.
- Both rovers carry a battery of scientific instruments to determine the history of the Martian climate and soil, allowing scientists to evaluate whether those conditions would have been suitable for life.

Facilitation notes:

- Eggs should be double-bagged in Ziplocs to prevent spillage.
- Have handi-wipes ready for breakage.
- One egg per team.

behind their design.

C. Teaching Points To Guide Reflection Questions:

- Forces and motion
- Design Process

Questions to encourage Teaching Points:

Did your design try to slow down the speed of the descent? How did you do this?
Did you try to cushion the egg rover? If so, how did you do this? Can you explain your approach? Was it successful and if not, what could you have done to improve upon your design?

Describe your design process. Was this your first design or did you modify a pervious one?
What science content did you apply to solve this problem?
How did JPL/NASA cushion the landing of Spirit and Opportunity?

D. Clean Up: Reduce! Re-Use! Recycle!

Only throw away items that cannot be re-used. All items should be returned to the appropriate place.

Extensions:
1) Research design of Spirit and Opportunity. What were the constraints that the JPL/NASA scientists faced? What factors did they consider in their design? What tradeoffs did they make? What materials did they use?
2) Design a system that not only protects the egg/instruments from impact, but also can deploy them for use on Mars.

RESOURCES

- *Conceptual Physics for Parents and Teachers: Mechanics* by Paul Hewitt. Focus Publishing/ R. Pullins Company, Newburyport, MA. 1998.

General physics sites:

- Rutgers University Physics Education Resource website: http://www.physics.rutgers.edu/hex/visit/lesson/lesson_index.html
- The Physics Classroom tutorial website: http://www.physicsclassroom.com/Default2.html
- Rader's Physics for Kids website: http://www.physics4kids.com

Mars Exploration sites:

- http://mars.jpl.nasa.gov/
- http://athena.cornell.edu/home/index.shtml
- http://cmex-www.arc.nasa.gov/Education/MPF_Model/main.html (Build your own model Mars Pathfinder)

Egg drop sites:

- http://quest.arc.nasa.gov/lfm/teachers/tg/program3/3.1.html
- http://www.learnnc.org/learnnc/lessonp.nsf/docunid/749458B94BD2F2EA852569610051FC5C?openDocument
- http://www.educ.drake.edu/sci_ed/elem_sci/phys/eggtlesson.html
- http://www.astrocappella.com/activities/land_safely.html

Glossary & Concepts:

Physics Terms

- Acceleration: The rate at which an object changes its velocity. An object is accelerating if it is changing its velocity, both speeding up or slowing down.
- Air resistance: The friction that acts on something moving through air.
- Elastic Potential Energy: Potential energy due to tension -- either stretch (rubber bands, etc.) or compression (springs, etc.).
- Energy: "Nature's way of keeping score." Measured in joules. Appears in many forms, most of which are ultimately derived from the sun or from radioactivity.
- Force: A push or pull. The force applied to a machine is called work input or effort force.
- Friction: Forces resisting motion between one set of molecules and another due to electrical attraction and repulsion, usually between two solid surfaces; static before motion starts and kinetic during motion.
- Gravitational Potential Energy: Potential energy due to elevated position. Gravitation potential energy = weight x height. Note this only depends on vertical displacement

and not the path taken to get it there. This value is always relative to some reference level.

- Inertia: The tendency of matter to remain at rest if at rest, or, if moving, to keep moving in the same direction, unless affected by an outside (or unbalanced) force.
- Kinetic Energy (KE): Energy of motion. KE= ½ mass x velocity^2 = ½ mv^2 Note that small changes in speed can result in large changes of KE (it's speed squared!). Net force x distance = KE. Includes heat, sound, and light (motion of molecules). KE is a scalar quantity; it cannot be canceled.
- Mass: the amount of matter that is contained by an object.
- Mechanical Energy: Energy possessed by an object due to its motion or its stored energy of position. Mechanical energy can be either kinetic energy (energy of motion) or potential energy (stored energy of position).
- Momentum: The quantity of motion of a moving object, equal to the product of its mass and its velocity.
- Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electric batteries, and the food we eat.
- Terminal Velocity: The velocity attained by an object wherein the resistive forces counterbalance the driving forces, so motion is without acceleration.
- Velocity (speed): How fast an object is moving. The distance traveled over time.

Newton's Law of Momentum Conservation:

The amount of momentum remains constant - momentum is neither created nor destroyed, but only changed through the action of **forces.**

Newton's Law of Conservation of Energy:

Energy cannot be created or destroyed; it may be transformed from one form into another, or transferred from one place to another, but the total amount of energy never changes.

Newton's Laws of Motion:

1st Law (Law of Inertia):

An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

2nd Law:

When an unbalanced force acts on a body, it is accelerated in the direction of the force; the magnitude of the acceleration is directly proportional to the force and inversely proportional to the mass of the body… **F=ma**