

# *Rovers from Junk*

## Teacher Background

Robots and robotic rovers are fascinating to most students and provide enough material to consume many hours of class time! The Activity suggested here uses simple items and takes just a few class periods. For those who are bitten by the robot bug, however, there are activities that introduce students to sophisticated devices that more closely mimic robots used in space exploration and demonstrate other important scientific and engineering principles.

This Activity will center around wind (balloon) and rubber band-powered rovers. They are simple, inexpensive and easy to make, but are not as practical for teaching about motion as rovers powered by electric motors. Small, battery-powered motors cost a few dollars and solar cells can be added to investigate rovers powered by solar energy.

## Objectives

- Students will construct robots from simple materials and use them to investigate physical concepts including mass, center of mass, torque, and friction.
- Students will explain (infer) how problems they encounter in robot construction relates to the design of
- planetary rovers.
- Students will research, plan and construct a rover test-bed that simulates the martian environment and the
- challenge faced by the NASA engineers who built the Mars rover.

## Vocabulary

autonomous, center of mass, lander, robotics, rover

MPF Project Educator Meredith Olson reports students have had great success using round pizza trays and a crutch! Emphasizing the value of learning from experiment, she also had students use a toilet paper tube for a chassis, and push-up yogurt containers for wheels. She writes, "We want students to recognize that ingenious activity can be done everywhere. They do not need to wait to have spiffy equipment to be clever in the way they solve everyday problems... 'Right answers come from making the materials perform better, not from doing it the way a teacher may say it should be.'" Push the engineering envelope and your students' imaginations!

## Materials

### Materials: For each Rover Development Team:

- eight 12-inch wooden or plastic dowels
- two 3-inch wooden or plastic dowels
- two 18-inch wooden or plastic dowels
- a couple of square feet of stiff cardboard
- 3-4 balloons
- rubber bands of different strengths and lengths
- several plastic drinking straws
- several bamboo skewers (from grocery store)
- a piece of flexible mesh gutter guard (for house gutters)
- 3/8 inch plastic tubing

a pair of strong scissors  
several pieces of modeling clay the size of golf balls  
duct tape  
protractor  
large rectangular sponge  
large button with holes  
wooden dowel about 6 inches long

### **Materials: For the rover test bed (Mars landscape):**

several plywood boards or very stiff pieces of cardboard each at least 1 foot x 2 feet in size  
several pieces of coarse and fine grain sand paper  
several pieces of aluminum foil  
a couple of piles of books  
strong tape  
several rocks or other objects, each an inch or two high and several inches long (to serve as obstacles)  
Any other materials students can find at school or home, suggested by them or thought of during an in-class brainstorming session.

### **Engage**

Ask students to demonstrate how big they think the Pathfinder rover was. Then show them a box that is roughly the same size as the rover (height: 28 cm, length: 63 cm, and width: 48 cm; about the size of a laser printer, but much lighter). Explain that this is the size of the rover body without its wheels. Discuss.

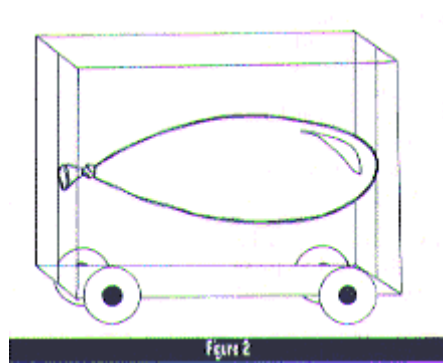
### **Explore/Explain**

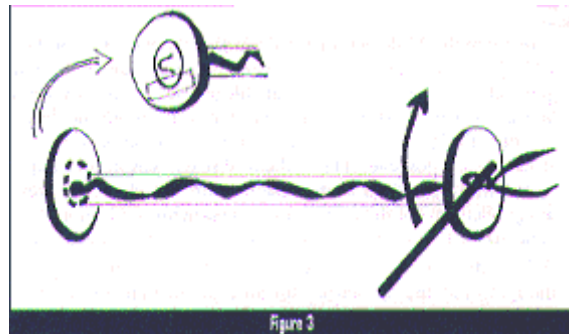
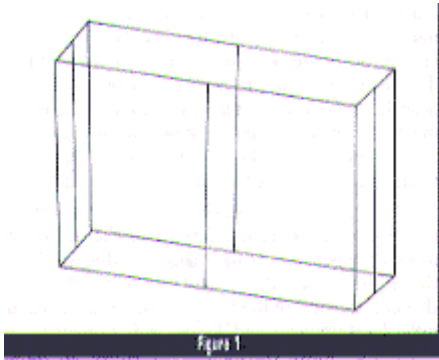
In this Activity students are going to problem solve and simulate the work of a Rover Development Team, creating and testing their own mechanical robotic-rovers. (This Activity can be as open or closed ended as you wish. Some educators may prefer to allow free-form experimentation, relying on student trial and error to arrive at final designs. These can be passed on to the students from the beginning or used to offer guidance only when they run into difficulty.)

### **Procedure**

1. Distribute the 12 dowels or plastic rods, a piece of stiff cardboard that is 3 x 18 inches, some duct tape, and several pieces of clay each about the size of a golf ball. (Note: commercially available plastic building set materials may also be used if they are sturdy.) Instruct each team to use the dowels/rods, the cardboard and the tape to construct as sturdy a structure as possible. Have them discuss, construct, non-destructively test, and share designs with the class. List key design elements of the most sturdy constructions. Caution students to try to use equal amounts of tape at each of the joints.
2. When they are finished, explain that this structure may be thought of as the framework for an experimental robot rover (Fig. 1). Ultimately, wheels will need to be placed on the frame so it can move, but first they need to experiment with the structure of the frame and develop ideas about where instruments might be placed within. Tell them that in doing this, they must keep in mind the center of mass of the system because that will affect whether the rover might tip over when encountering a large rock.
3. Explain that the pieces of clay represent instruments to be put in the rover. Have students experiment with attaching a piece of clay near the top of one of the long sides of the frame. Have them determine the new center of mass. Next, have them slowly and carefully begin to tip the frame over so that the clay hangs over the edge of the structure.

4. Using their protractors, have students determine at what angle the structure becomes unstable, i.e., tips over. Record the results. Next have students do the same by placing the same piece of clay near the top of the short side of the frame. Repeat the center of mass determination and the tipping experiment and record the results. Discuss the difference. Challenge students to draw conclusions.
5. Students should repeat the above experiments, this time placing the piece of clay near the bottom of the sides but before they do, challenge them to make hypotheses as to what effect this will have on the center of mass and tip-over angles. Record the results, discuss and re-examine their hypotheses. Discuss. Next, have them place the clay in the center of the bottom of the frame, i.e., in the middle of the piece of cardboard. Again make measurements and discuss. Ask students to conclude where they would place the heaviest instruments within the frame to maximize the stability of the robot when climbing over rocks or other rough terrain. Challenge them to redesign the shape of the frame to increase the overall stability of the rover. (Older students could calculate the volume of the frame and design a new, more stable frame in a different shape but with the same total volume).
6. Discuss wheels. Ask students to draw conclusions as to the best size wheels to use on the original frame and/or their redesigned frame. What advantage do large wheels have? Is there a limit to the size of wheels that can be used for a particular sized frame? Why? If a total of 4 wheels on two axles are to be used, where is the best place to put the axles. Are two axles the best? Why, or why not? Should they be close together or far apart? Should they be right at the front and way in the back? Does the answer depend on the weight distribution of the instruments? Remind them how their decisions will likely affect the C.M. and overall stability of the rover.
7. Distribute more cardboard, scissors, dowels and straws to each team and have them cut out and add the wheels and axles to their frames. Once complete, have them experiment again with the C.M. and determine the tip over angles of their wheeled rovers. What effect did the wheels and axles have on the C.M.? Did they help or hurt the overall stability? Have each team determine how big a rock their rovers can negotiate, under two different conditions: (1) if the rock passes directly under the rover and, (2) if the rock passes under one or more wheels.
8. After appropriate rover redesigns, clear an area in the hall, gym or play ground and have an "Ares Vallis 500". Award prizes for the teams whose rovers went the farthest and/or the fastest. Discuss with the class the differences in design which led to the winners. Ask them if speed is necessarily a good thing for a planetary rover, especially if it's maneuvering in unknown terrain.
9. Next, have the class design a course for the rovers to navigate. Use appropriate pieces of stiff cardboard, books, tape, different kinds of sand paper, loose sand and rocks. An example is shown below. Have each team run their rover over the course one at a time. Note which rovers succeeded, which failed, and why. Challenge each team to make adjustments in their rovers (or make overall adjustments to the course if it seems too challenging for most) and run the trials again. Discuss all that was learned.





### Center of Mass (C.M.) demonstration:

Explain that all objects have a center of mass--a point at which the object balances. Hold up a meter stick and ask students where you would have to put your finger to balance it. Demonstrate that their likely guess at the 50 cm mark was correct. Next, tape a coin on one end of the stick and repeat the question. Repeat with two coins taped to one end, each time demonstrating the new center of mass. Next move to a 3-dimensional object, like a ball. Hold it in different ways. Lead students to the correct notion that the C.M. is in the center of the sphere.

Produce a second ball inside which you have inserted a fairly large piece of modeling clay which is securely attached to interior side of the ball. Ask students where the center of mass is. (They will likely answer in the center). Hang this ball by a piece of string from various points. Ask students to infer what is happening. Help them to determine the C.M. of the second ball, and to realize that an object's C.M. is determined by how mass is distributed within that object. Discuss why this concept of center of mass is important to rover design.

### Powering the Rovers

#### Balloon Power:

##### Procedure

Challenge students in a class discussion or as part of individual design projects to come up with realistic ways of propelling their rovers over rough terrain. Blow up a balloon and let it go, or remind students of their Activity using balloon rockets. Give each team a long balloon and challenge them to figure out a propulsion system that can be attached to their frames (Fig. 3).

Ask them to think about where the force of the balloon will be directed and challenge them to apply this knowledge to where, relative to the C.M. of the frame, they should place their balloon for maximum stability. When complete, have each team propel their rovers across the classroom. How could the system be improved? Redesign and test if necessary.

### Rubber Band Power:

Give each team a button, a large, strong rubber band and a dowel about as long as the diameter of one of their rover's wheels. Have them disassemble the rear wheels and axle and attach the rubber band as shown in Fig. 3. (or challenge them to figure out how to use these materials to power their rovers).

Have students wind up their rubber bands using the dowel attached to one of the wheels and, placing the rover on the floor, have each team test theirs in turn. Redesign, if necessary, for improvements. Note that the tighter the rubber band is wound, the more powerfully and faster energy is transferred to the rear wheels. Is there such a thing as having too much power transferred too quickly? What happens if this occurs? Challenge students to consider and investigate the effects of using different sized wheels, the materials and design of the wheels themselves (see the image of Sojourner on the LFM poster, and on the accompanying NASA publication) and the nature of the surface on which the rover moves. Make changes if possible including covering the rims of the wheels with coarse rubber or thin strips from a rectangular sponge. This can lead to an important discussion of friction and even torque among older students.

### Expand/Adapt/ Connect

Challenge students to take what they have learned from this Activity and use it to design a more advanced robot rover. Tell them that, in this hypothetical case, they might have a budget of a few hundred dollars. Ask them what such a rover could do that their simple rovers could not. Discuss this in light of the fact that a planetary rover is a long distance from Earth where two-way communication can take a long time and the terrain can be very unfamiliar.

Students may also want to investigate and build a Bogie rover with a separate hinged set of wheels. Such designs have advantages in planetary investigations because they add greater capability in helping rovers maneuver over rocks and other uneven terrain. Have them take such a rover by hand over their course, feeling the forces encountered as the rover confronts obstacles. Discuss advantages of the rocker bogie design over the fixed axle designs they built before.

Go on-line and research Sojourner's actual design in greater depth.

Discuss how their own rocker bogie design is similar or different.

When running the rover over their Mars terrains, students might want to add a time-delay handicap simulating the time involved in sending messages between Earth and Mars.

Schools might want to collaborate with other schools via e-mail and teleconferencing (CU-SeeMe), exchanging ideas and actually directing rovers at remote locations.

### Suggested URLs

<http://robotics.jpl.nasa.gov/>

<http://img.arc.nasa.gov/>

© PASSPORT TO KNOWLEDGE