

Designing Vehicles to Meet Requirements

Overview and Objectives

In previous lessons, students gained experience in setting up systems to investigate the motion of vehicles and tested the effects of force and load on the vehicles' motion. In this lesson, students receive a design challenge: they must apply information collected in Lessons 3 and 4 to their own design of vehicles that move a specified distance in a specified amount of time. Students meet this challenge by using problem-solving skills to adjust the load on their vehicles, the force pulling the vehicles, and the weight of the vehicles themselves. As they modify the design of their vehicles by adding or removing pieces, students apply their knowledge of how weight and load affect a vehicle's motion.

- Students design vehicles and systems to pull the vehicles to meet time requirements.
- Students use and apply previously collected data to design their systems.
- Students read to learn more about a specialized vehicle, the Lunar Rover.

Background

In Lesson 3, students learned that a lighter weight on the end of the string produced slower vehicle motion. In Lesson 4, they learned that heavier loads carried by the vehicle produced slower changes in vehicle speed. Now they must apply both of these findings to meet a design requirement: The vehicle must move a distance equal to the height of the work space in four to six seconds.

Students' first inclination might be to use the heaviest load and the smallest number of washers in their system. However, they may find that as they increase the load to slow the vehicle, they must also add washers to the end of the string just to keep the vehicle moving. Likewise, if they reduce the number of washers, the vehicle may not move at all. This is an interesting problem for which there are many solutions. Several combinations of blocks and washers will meet the design requirement. In solving the challenge, students might also decide to add friction to their systems. For example, they might attach and drag washers from the rear of their vehicle to increase friction and reduce speed. Students might also grasp that the more building pieces they add to their vehicle, the greater the vehicle's weight and the more difficult it may be to get the vehicle moving.

Like engineers, students in this lesson plan, build, test, evaluate, modify, and retest their vehicles before presenting the results. By following a technological design process, they will apply scientific concepts to meet requirements. To plan and implement their investigation, students will need to refer to recorded data from earlier lessons.

Materials*For each student*

- 1 science notebook
- 1 pencil with eraser

For each group of three students

- 1 design challenge card
- 1 standard vehicle
- 1 bucket of building pieces
- 1 small bookend with nonslip base, 13h × 12w × 13d cm (5h × 4¾w × 5d in), about 141 g (5 oz)
- 1 string with paper clip hooks, wrapped around cardboard (from Lesson 4)
- 16 small washers in cup
- 3 large washers
- 2 blocks of wood, 5 × 8 × 9 cm (2 × 3 × 3½ in)
- 1 timer
- 1 circle template
- 1 metric ruler
- 1 set of colored pencils (to match building pieces)
- 1 strip of Masonite™, 38 × 122 × 0.6 cm (15 × 48 × ¼ in), or foamboard, 38 × 122 × 0.5 cm (15 × 48 × ⅙ in) (optional)

For the class

- 1 **Design Challenge Card: Lesson 5** (blackline master, pg. 70)
- 1 sheet of newsprint
- 1 measuring tape, 100 cm (39 in)
- Assorted colored markers
- Masking tape
- Extra string
- Jumbo paper clips
- Scissors
- Trade books on load-bearing vehicles

Preparation

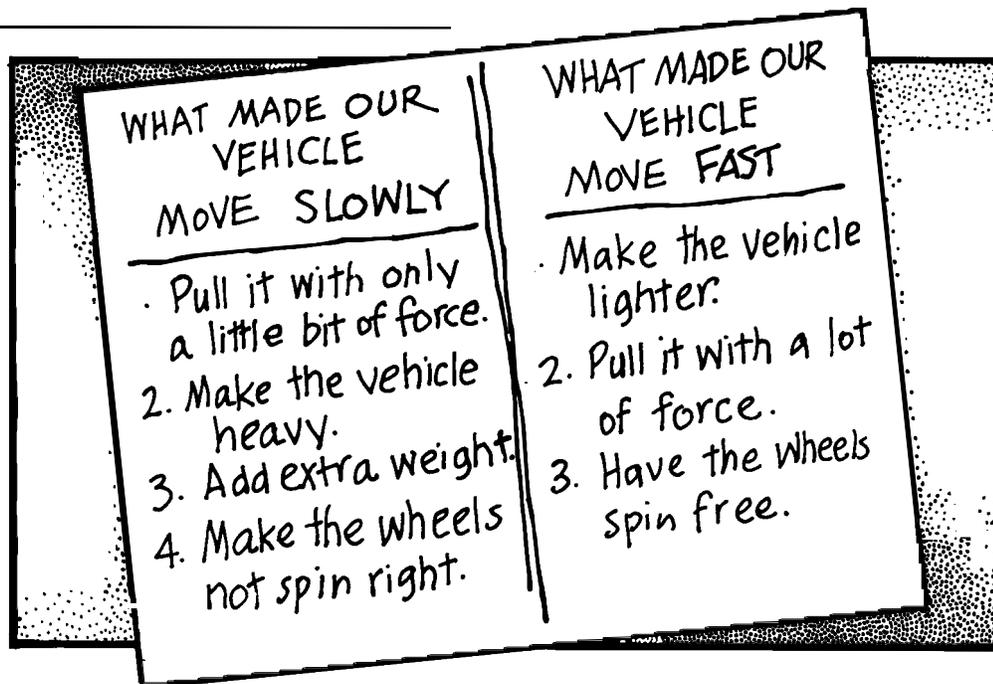
1. Copy **Design Challenge Card: Lesson 5** (blackline master, pg. 70). Note that the blackline master contains two copies of the same challenge card. Cut each duplicated sheet into two cards. Each group needs one card.
2. Create two columns on the newsprint. Label the columns “What Made Our Vehicles Move Slowly” and “What Made Our Vehicles Move Fast.” Date and hang the sheet.
3. Check each group’s string with hooks. If a string is knotted, prepare a new one.
4. Arrange the materials at the distribution center.
5. Collect trade books that illustrate various load-bearing vehicles (such as trucks, minivans, moving vans, tractor trailers, wagons). Display the books for students to research various designs.

Procedure

1. Direct students' attention to the labeled newsprint. Ask students to write a few sentences in their notebooks about what caused their vehicles to move slowly and what caused them to move fast when they used the falling-weight system in Lessons 3 and 4.
2. Have students share their responses with the class. Using colored markers, record their ideas on the newsprint list in the appropriate columns. Sample student responses are shown in Figure 5-1. Ask students to brainstorm situations in which a vehicle would be required to move slowly or quickly.

Figure 5-1

Sample
brainstorming list



3. Distribute one design challenge card to each group. Make certain students understand the requirements of the challenge. Discuss how they can apply the information collected in Lessons 3 and 4 to the challenge in this lesson.
4. Remind groups to give each member an opportunity to manipulate the building pieces and to help build the group's vehicle. Explain that once groups have met the challenge, they must be able to repeat their results for the teacher, another group, or the class. Ask students why repeatable results are important in science and engineering.
5. Ask groups to get their vehicles, trade books, and other materials and begin the design challenge. Students should set up their falling-weight systems just as they did in Lessons 3 and 4. They will also use a timer in this lesson.

Final Activities

1. Ask students to describe the process they used to build their vehicles and test the vehicles' motion. Use questions such as the following to guide the discussion:
 - **Designing and Planning:** Before building your vehicle, how did your group prepare?
 - **Building:** Did you experience any problems as you were building your vehicle? How did you solve them?

- **Testing:** How did you test your vehicle to determine whether it met the requirements? How did your vehicle move?
 - **Evaluating:** Did you change anything about your vehicle or the falling-weight system after you tested it? What change did you make? Why did you make this change?
2. Have students use their pencils, colored pencils, circle templates, rulers, and graph paper to make a record (drawing) of their vehicles. (Students can use Figure 5-1 on pg. 25 of the Student Activity Book as a model.)
 3. Ask students to clean up by doing the following:
 - Remove the building pieces you added to your vehicles in this lesson. What should remain is the standard vehicle built in Lesson 2. You will use the standard vehicle again in Lesson 6. Students can refer to the technical drawing of the standard vehicle in Lesson 2 (pg. 36), if needed.
 - Place any extra building pieces in your buckets.
 - Return your standard vehicles and all other materials to the distribution center. Give the string and hooks to your teacher.
 - Return the empty cardboard to the distribution center. You will use it in Lesson 9.



Management Tip: The following step can be completed now or at another time, such as during language arts.

4. Have students meet in pairs and read “Lunar Rover: Making Tracks on the Moon” (pgs. 68–69 in this guide and pgs. 26–27 in the Student Activity Book). As students read, ask them to think about why engineers designed this specialized vehicle to move slowly.

Extensions

SOCIAL STUDIES

LANGUAGE ARTS

Have students survey adults to determine how many of them use design principles in their work. Students can also ask the interviewees in what ways they use design principles in their work. They can publish the interviews or a summary of their findings in a *Technological Design Newsletter* that they create. Encourage them to draw pictures or take photographs to include in the newsletter.

MATHEMATICS

2. Ask students to take repeated measurements of the time it takes their vehicles to move 60 cm (23½ in). Have students graph their data using a line plot (as in Lesson 4) or a line graph.

LANGUAGE ARTS

SOCIAL STUDIES

3. Have students research the airplane *Voyager*, which was the first plane designed to fly around the world without stopping to refuel. Ask them to answer the following questions. When did the *Voyager* make its first flight? How long did it take the plane to fly around the world? What design features of the plane helped save fuel?

SCIENCE

ART

4. Students can design and make their own paper airplanes. After a test flight, have students change the features of their paper airplanes to make them fly farther.

Assessment

In this lesson, students apply previously collected data and learned concepts and skills to the solution of their design challenge. As students build and test their vehicles, take notes on each student's progress. Use the following questions to help in your assessment.

Meeting the Design Challenge

- Does the student understand that the vehicle must meet a design requirement?
- Does the student understand what the requirement is?
- Does the student work cooperatively in the group in planning how to meet the design challenge? Does the group record its plan? (a sketch of the vehicle design, a written record of the number of washers)
- After building the vehicle, does the student work with the group to test it and evaluate its performance?
- If the vehicle does not initially meet the requirement, does the student work with the group to make a plan for improving the vehicle? Is the plan related to the test results?
- Does the student keep written records of test results?

Recording a Design

At the close of this lesson, you asked students to draw a representation of their vehicle. That drawing, together with the drawing from Lesson 2 and future lessons, can be used to assess improvement in each student's ability to record a design. Use the following questions to assist in the assessment:

- Does the student show improvement in his or her drawing ability?
- Does the student use a variety of techniques to make the drawings clear and easy to read? (color, labels, building pieces drawn in proportion) Did the student use these techniques in Lesson 2?
- Can the student effectively use drawing tools, such as a circle template, ruler, and colored pencils?
- Can the student draw the vehicle from one perspective? Or does the student combine several perspectives in one drawing?
- Does the student choose a perspective that clearly shows important features of the vehicle?
- Does the student create several drawings, each showing a different perspective?

Preparation for Lesson 6

At the end of this lesson, students should have removed from their vehicles all the pieces that are not part of the standard vehicle. They will need standard vehicles in Lesson 6.

Reading Selection

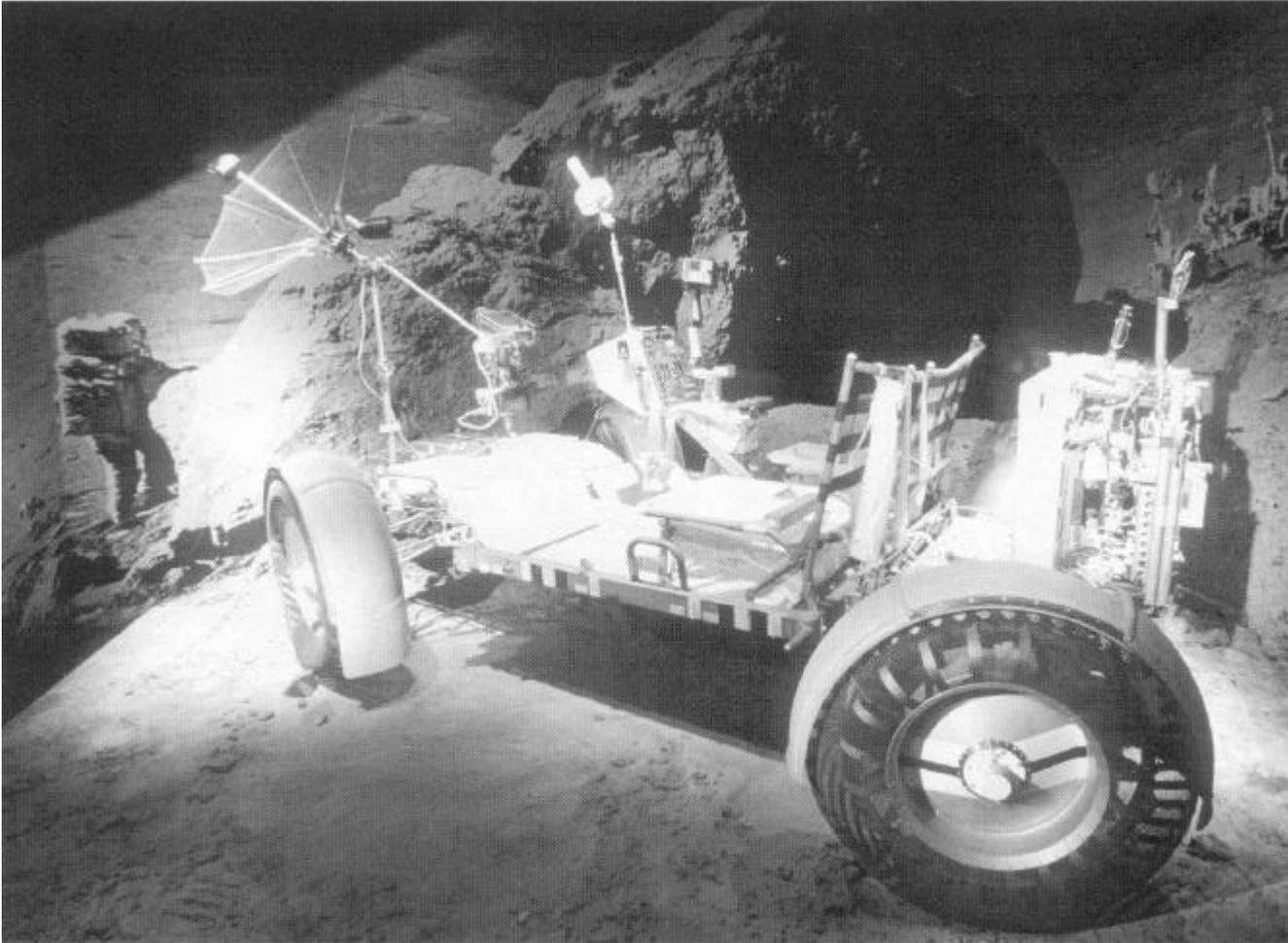
Lunar Rover: Making Tracks on the Moon

Photo: Dane Penland. Courtesy of National Air and Space Museum, Smithsonian Institution.

Lunar Rover

Just imagine that you are an astronaut. Suppose you are flying a spacecraft to the Moon. Your goal is to learn about the Moon's surface. What kind of vehicle would you like to have there?

Engineers have already answered this question. In the Apollo space program, U.S. astronauts flew to the Moon. On many of these flights, the astronauts landed and walked on the Moon's surface. They took samples of Moon rocks and performed many scientific experiments. But since their oxygen supply was limited, they could only walk about 1 km ($\frac{1}{2}$ mile) away from their

spacecraft. Many places they wanted to investigate were too far away.

To help the astronauts in their work on the moon, engineers designed a vehicle called the Lunar Rover. It was big enough to hold two astronauts, their equipment, and many samples of Moon rocks. What were the Lunar Rover's design requirements?

First of all, the Lunar Rover had to be light enough so that a rocket could lift it off Earth. The Rover weighed 210 kg (462 lb) on Earth. It only weighed 35 kg (77 lb) on the Moon. Do you know why?

How did the Lunar Rover get its energy to move? Most cars on Earth burn gasoline to drive their engines. Burning gasoline requires oxygen and oxygen comes from the air. Because there is no air on the Moon, a gasoline engine would not work. Instead, the Rover used electric motors, one for each wheel. Energy for the motors came from batteries.

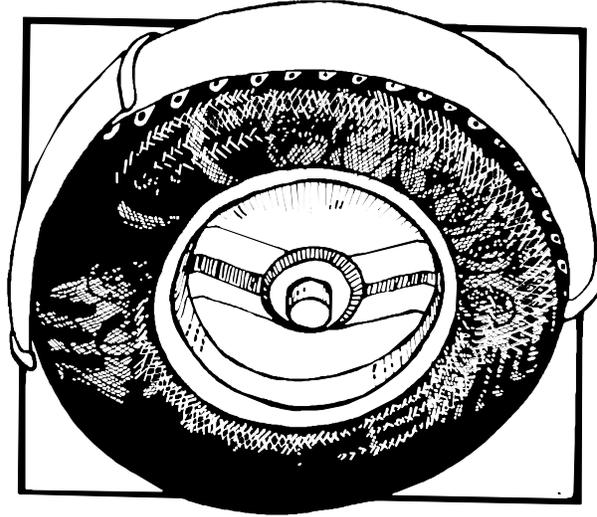
The Rover had to move over the Moon's surface. Some of that surface is rough and uneven. The engineers made the tires big enough so that the Rover could roll over small bumps and cracks. To save on weight, engineers made these tires of wire. The

tires looked like round metal cages, just like the cage around a small electric fan.

The Lunar Rover's top speed was about 12 km (7 miles) per hour. It needed to move slowly to save on the battery. The slow speed also helped astronauts control the vehicle on the rough terrain.

Engineers made careful records of their design for the Lunar Rover. They also recorded the results of all tests.

Suppose engineers needed to build a vehicle to explore the surface of another planet, like Mars. What might this vehicle look like? Do some research and find out!



Close-up of Lunar Rover's tire

Design Challenge Card: Lesson 5



Design Challenge

You are part of a famous engineering design team. Your team has been hired by “Out-of-This-World Vehicles,” a company that specializes in designing space exploration vehicles. Your team must design and build a lunar vehicle that will move slowly on wheels across the lunar surface while being pulled by a rope. The design requirements are the following:

- Start with the standard vehicle. Add building pieces to make your design unique. Be creative.
- Your vehicle must be able to carry large lunar rocks (represented by blocks).
- Your vehicle must move across your work space in 4 to 6 seconds while being pulled by a rope.
- Deadline: You will have 30 minutes to complete the design challenge.

Good luck!



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