Lunar Rover

Background

This problem applies mathematical principles in NASA's human spaceflight.

Exploration expands human presence into the solar system providing the foundation of our knowledge, technology, resources, and inspiration. It seeks answers to fundamental questions about our existence, responds to recent discoveries, and puts in place revolutionary techniques and capabilities to inspire our nation, the world, and the next generation. Through NASA, we touch the unknown; we learn and we understand. As we take our first steps toward sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future.

In 1971, the Apollo 15 mission was the first mission to carry a lunar roving vehicle (LRV). This LRV (Figure 1) allowed astronauts to travel farther from their landing sites than in previous missions and explore and sample a much wider variety of lunar materials.

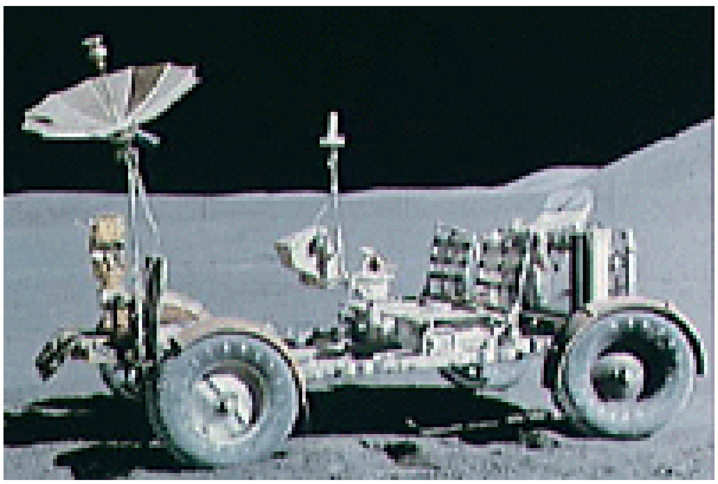


Figure 1: Apollo 15 Lunar Roving Vehicle taken on the Moon (NASA)

Because the vehicle was unpressurized, its longest single trip was 12.5 kilometers (7.8 miles). Its maximum range from the Lunar Module (LM) was 5.0 kilometers (3.1 miles). LRVs were also used during Apollo 16 and 17 missions in 1972.

If the LRV were to have failed at any time during the extravehicular activity (EVA), the astronauts had to have sufficient life support consumables to be able to walk back to the LM. This distance is called the "walkback limit", and it was approximately 10 kilometers (about 6 miles). Because of the reliability of the LRV and of the spacesuits, this restriction was relaxed on Apollo 17 for the longest traverse from the landing site—about 20 kilometers (or 12 miles).

As NASA returns to the Moon and begins to explore other surfaces (such as Mars), exploration rovers will once again be needed to allow astronauts to traverse the terrain. Modern unpressurized rovers, which steer like cars, will look similar to those of the Apollo years (Figure 2) These vehicles will be limited to local travel of 10 to 20 kilometers (about 6 to12 miles) from the outpost site, where the astronauts would live on the Moon, for short periods of time (less than 10 hours), and will still require astronauts to wear space suits while traveling.

Figure 2: Unpressurized Rovers (NASA concept)

A second roving vehicle concept, pressurized rovers, will give astronauts the ability to travel long distances (up to 200 kilometers) and perform extended science missions away from their habitat (Figure 3). They will provide a comfortable indoor environment for driving, while allowing the crew to use a variety of sensing and manipulation tools. These features will enable exploration and science to be performed without the need to exit the vehicle. Additional concepts for the pressurized rover include docking ports which allow the crew to directly enter the rover from their habitat and an airlock which permits extravehicular activity*.* The versatility of this rover, its power system, and its life support system will allow the astronauts to spend multiple Earth days away from their habitat performing work.

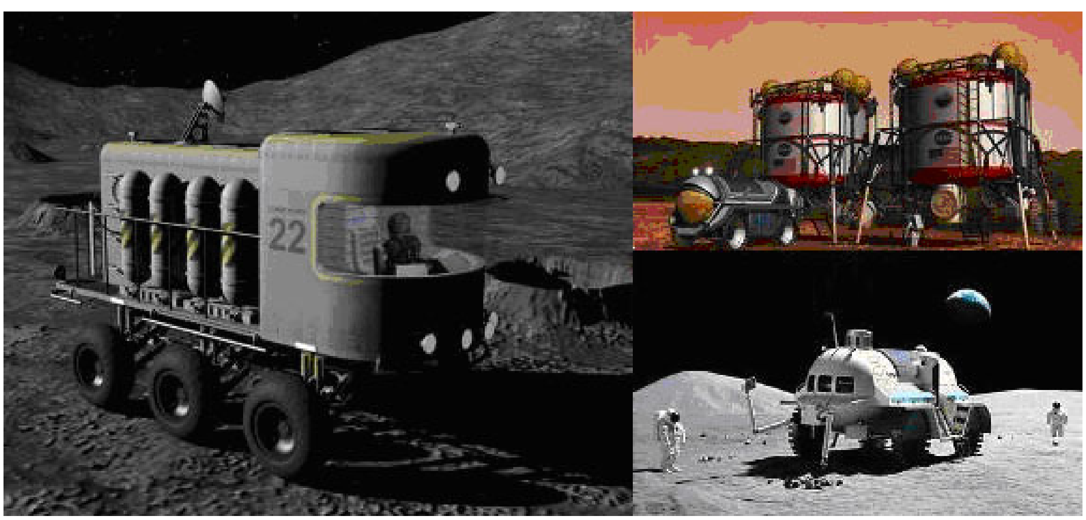


Figure 3: Pressurized Rovers (Artist concepts)

Instructional Objectives

- You will create a scale drawing to model a real life problem.
- You will apply the Pythagorean Theorem and distance/rate formula ($d = rt$).
- You will analyze data to find a solution.

Directions: Read through the problem set-up and answer the following questions.

Problem

You are on the mission planning team that will determine the best crew route to be used on the first trip to the Moon using the new pressurized LRV (Rover 1). In this scenario, the crew must use Rover 1 to gather rock samples from around the deGerlache Crater.

On the map, Rover 1 is located at Habitat A (near Shackleton Crater). Crewmembers must drive Rover 1 to the rim of deGerlache Crater to collect rock samples. Rocks can be collected at any point along the edge of the crater (along segment $\overline{PQ}$ on the map). Before Rover 1 and the crew return to the habitat, they must also stop at point B on the map in order to reset a seismic sensor that has been gathering data about the interior of the Moon. All distances are denoted on the problem diagram (Figure 4).

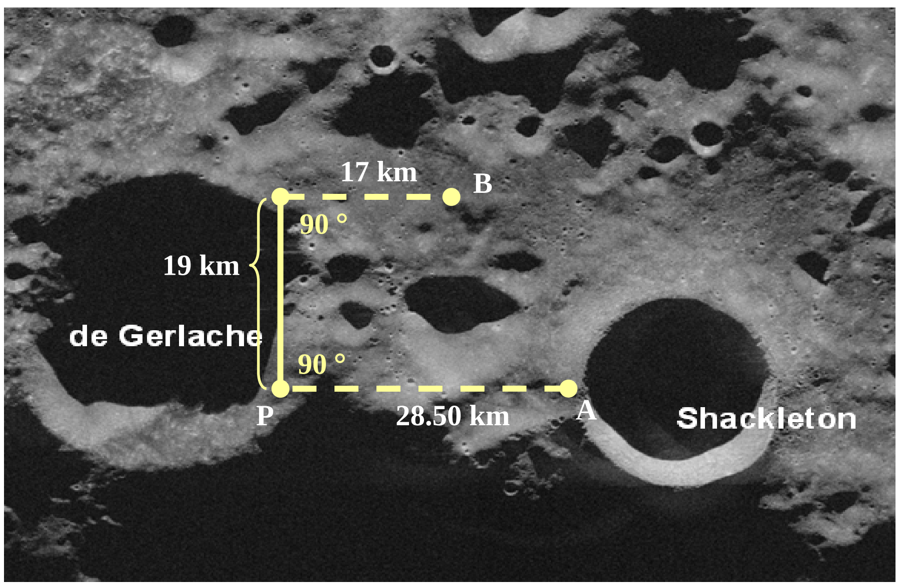


Figure 4: Problem diagram

Directions: Answer questions 1.a–1.c. in your group. Discuss answers to be sure everyone understands and agrees on the solutions. Round all answers to the nearest thousandth, and label with the appropriate units.

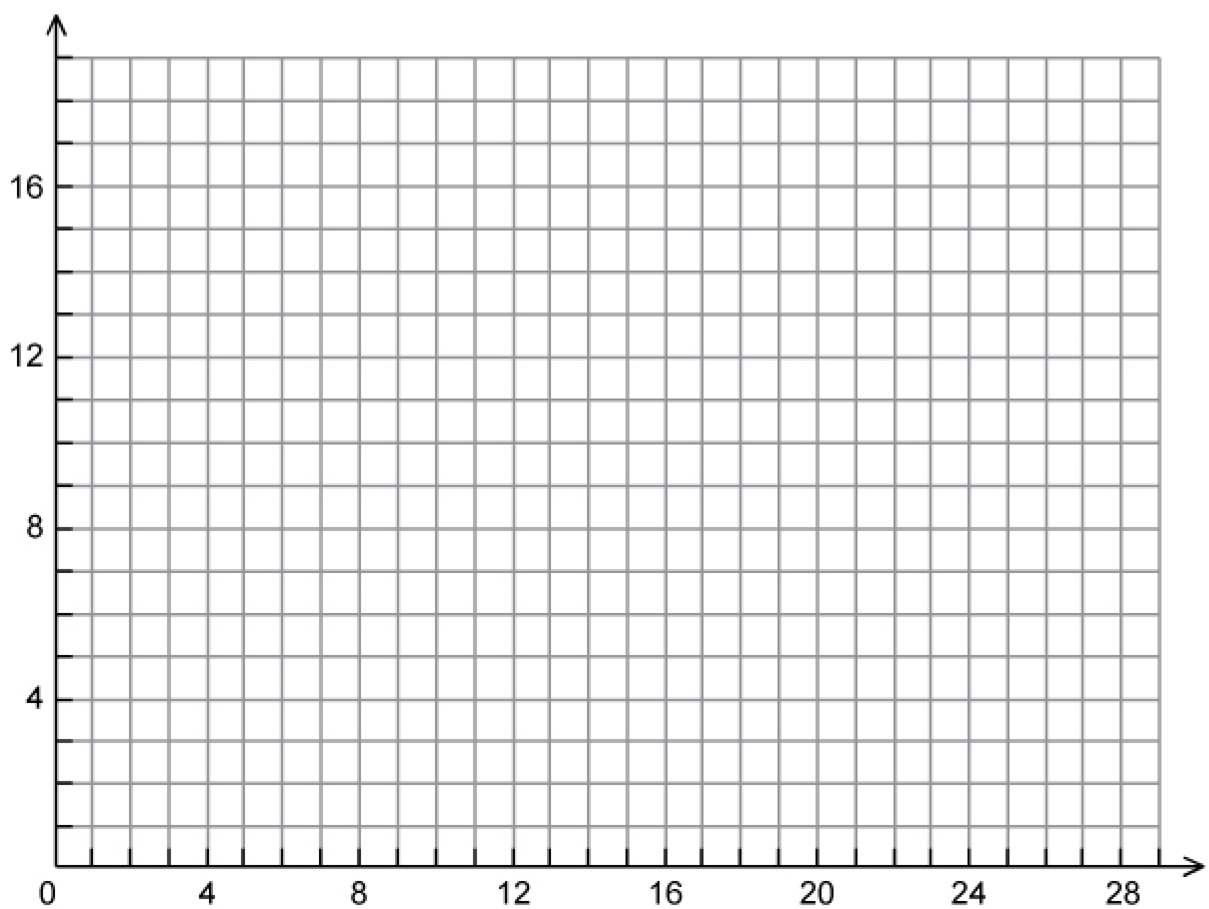
1. Minimal Path Problem

   Your mission planning team must find the shortest total path for the pressurized Rover 1 to travel for this exploration.

   - The crew will start at Habitat A and travel to a point along deGerlache Crater (on segment $\overline{PQ}$) to collect rock samples.
   - The crew will then travel to point B to reset the seismic sensor.

   a. Create a scale drawing of the mission on the graph provided (Graph 1).
      i. Point P is located at the origin
      ii. Segment $\overline{AP}$ lies on the x-axis
      iii. Segment $\overline{PQ}$ lies on the y-axis
      iv. Point B is located on the horizontal line through point Q
      v. Chose a point on $\overline{PQ}$ along the deGerlache Crater that you think would give the shortest total distance. Label that point G for "guess".

Graph 1: Lunar Rover Mission Graph



b. The crew may choose to travel from point A to point P to point B. Use a colored pencil and straight edge to draw this path on Graph 1. Using the Pythagorean Theorem to determine the distance from point P to point B, calculate the total distance from point A to point P to point B.

c. The crew may choose to travel from point A to point Q to point B. Use a different colored pencil and straight edge to draw this path on Graph 1. Using the Pythagorean Theorem to determine the distance from point A to point Q, calculate the total distance from point A to point Q to point B.

Directions: Answer questions 1.d.–1.i. in your group. Discuss answers to be sure everyone understands and agrees on the solutions. Round all answers to the nearest thousandth, and label with the appropriate units.

d. Suppose point C is located at (0,3). Using a third color, plot the point C(0,3) on segment $\overline{PQ}$. Draw the path of Rover 1 from point A to point C to point B. Discuss with your mission planning team how to calculate the total distance. Write a summary of the plan.

e. The Minimal Path Table (Table 1) can be used to assist your team in calculating the total distance from A to any point between point C to point B.
   i. The calculations to determine the total distance for the point discussed in Part 1.d. are shown in the table.
   ii. Discuss the reason for each process column with your team members.
   iii. Working with your mission planning team, select and plot a different location for point C on segment $\overline{PQ}$ that the group thinks will result in a shorter total distance, $\overline{AC} + \overline{CB}$. Complete the process columns in Table 1 for your group's new point.
   iv. Repeat the process with the other three points.

Table 1: Minimal Path Table

C (0, *n*)	$\overline{PC}$	$\overline{CQ}$	$\overline{AC}$	$\overline{CB}$	$\overline{AC}+\overline{CB}$
(0, 3)	*3 km*	*(19 – 3) km*	$\sqrt{(28.5\ km)^2+(3\ km)^2}$	$\sqrt{(17\ km)^2+(16\ km)^2}$	$\sqrt{(28.5\ km)^2+(3\ km)^2}+\sqrt{(17\ km)^2+(16\ km)^2}\approx 52.003\ km$

f. Working with your mission planning team, analyze your table. According to your data, where is the best location for point C so that the total distance Rover 1 travels is minimized? What is the distance traveled? Compare your results with those of two other teams. Does there seem to be one best location in order to minimize the path?

g. Given any point C(0, *n*) along segment $\overline{PQ}$, write an expression in terms of *n* and fill in the last row in Table 1. Use your process from previous rows to draw conclusions about the entries in the last row.

h. Enter the equation for the total distance into y1 in your graphing calculator. What is the domain for this function? Based on the total distance values in the table, what is an appropriate window for y-values? Graph the equation and use the minimum function of the calculator to approximate the minimum distance.

i. Show your solution on your mission graph by highlighting Rover 1's path for the shortest distance traveled. How close was your prediction, point G, for the shortest total distance to the actual value found?

Directions: Answer questions 2.a–2.d in your group. Discuss answers to be sure everyone understands and agrees on the solutions. Round all answers to the nearest thousandth, and label with the appropriate units.

2. Minimal Time Problem

The average speed of Rover 1 is 8.9 kilometers/hour with an empty payload. With a full payload of rocks, the average speed drops to 5.5 kilometers/hour.

a. Using the locations chosen in Problem 1 and the Minimal Time Table (Table 2), find the time required for each path.

Table 2: Minimal Time Table

C (0, *n*)	$\overline{\textbf{AC}}$	$\overline{\textbf{CB}}$	**Total Time,** $t = \frac{d}{r}$
(0, 3)	$\sqrt{(28.5\ km)^2 + (3\ km)^2}$	$\sqrt{(17\ km)^2 + (16\ km)^2}$	$\dfrac{\sqrt{(28.5\text{ km})^2 + (3\text{ km})^2}}{8.9\frac{km}{hr}} + \dfrac{\sqrt{(17\text{ km})^2 + (16\text{ km})^2}}{5.5\frac{km}{hr}}$ ≈ 7.464 hr
(0, *n*)			

b. According to your data, where is the best location for point C so that the total time traveled is minimized? What is the minimum time for the mission? Compare your results with those of two other teams. Based on the comparisons, what is the best location for point C to minimize the total time for the mission?

c. Enter the equation for the minimum time into y2 in your graphing calculator. Graph the equation and use the minimum function of the calculator to determine the minimum time. What is the best location for point C so that the total time traveled is minimized? What is the actual minimum time for the mission?

d. Show your solution on your mission graph by highlighting Rover 1's path for the minimum travel time. What is the difference in the minimum time your team determined in Part 1.b. and the actual minimum time?

Directions: Complete question 3 independently.

3. Now that you have determined both a minimum distance and a minimum time, which would you consider to be the better choice and why?

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