Exploring Space Through ALGEBRA

STUDENT EDITION

Geometry and Algebra II

Communications and the Lunar Outpost

Background

Exploration provides 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.

The vision for space exploration includes returning the space shuttle safely to flight, completing the International Space Station, developing a new exploration vehicle and all the systems needed for embarking on extended missions to the Moon, Mars, and beyond.

By 2020, NASA astronauts will again explore the surface of the moon. This time, we're going to stay, building outposts and paving the way for eventual journeys to Mars and beyond.

The crewed and robotic return to the Moon requires robust and reliable communications. It will be important to maintain constant communications with Earth. Therefore, 24 hours per day/7 days per week coverage at the outpost is a requirement. This will likely be accomplished by a combination of communication satellites in orbit around the Moon and communication equipment on the lunar surface.

The lunar habitat (Figure 1) on the Moon's surface will need video downlink capability to Earth. In addition to the communication requirements between the lunar surface and Earth, it will also be important to maintain constant communications between surface crew members, regardless of their distance from the outpost.

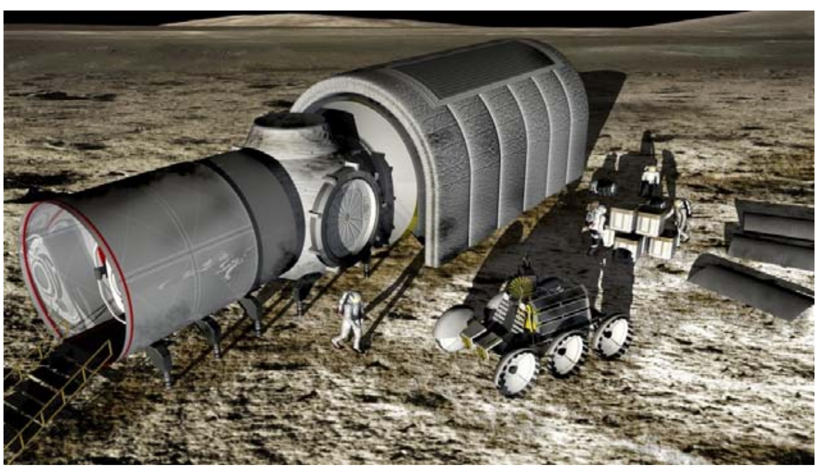

Figure 1: NASA Concept of a Lunar habitat, airlock, and vehicles (not to scale)

Surface to surface communications involves communicating between astronauts, rovers, robots, habitats, power stations, and science experiments, as well as communication within the habitats. For surface-based communication systems, there is a line of sight limitation on rover communication with the habitat. Astronauts must have either the habitat or the rover in their line of sight to maintain communications with Earth.

The communications system should be easily expandable. Future missions will not want to abandon existing equipment, but instead incorporate existing equipment into an expanding lunar communications system.

These plans give NASA a huge head start in getting to Mars. We will already have rockets capable of transporting heavy cargo as well as a versatile crew capsule. A lunar outpost just three days away from Earth will give us needed practice of "living off the land" away from our home planet, before making the longer trek to Mars.

For more information about lunar outposts, communications and the U.S. Space Exploration policy, visit www.nasa.gov.

Instructional Objectives

- You will use algebraic properties to solve equations for a given variable.
- You will apply formulas to calculate various geometric measures.
- You will analyze data to determine a solution to a real life problem.

Problem

Suppose a lunar outpost has been established on the rim of Shackleton crater. Shackleton crater is small, about 19 kilometers in diameter, and is not in range of any satellite. The rim is slightly raised and in an area of near-permanent sunlight that provides access to solar power. The crater's permanently dark interior is a cold trap that may contain water ice. This site is within the South Pole-Aitken (SPA) basin, the oldest and biggest impact feature on the Moon. The SPA basin is about 12 kilometers deep and exploration of its geologic features may provide useful information about the lunar interior.

Whenever astronauts travel away from the lunar outpost for scientific study or exploration, constant communications will be provided by surface to surface communication towers. Receivers within a certain radius of the communication tower antenna can pick up signals. Because the Moon is a sphere, the surface to surface signals cannot be received beyond the point of tangency, P, of the line of sight distance, *d* (Figure 2).

Precision in these calculations will be critical to the communication signal, therefore carry all calculations to two decimal places. Also, if you are using a calculator, make sure it is set to degrees (not radians).

The following diagrams will help you answer the questions that follow.

h = tower height

r = radius of the Moon (1738.14 km)

d = line of sight distance

P = point of tangency

a = arc length

θ = central angle measure

C = circumference

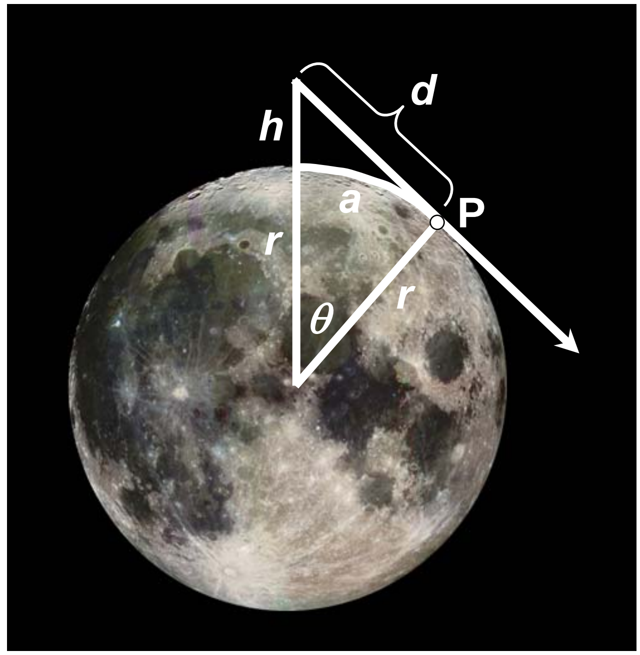

Figure 2: Problem Diagram
NOTE: Diagram is exaggerated to show relationship and reference points.

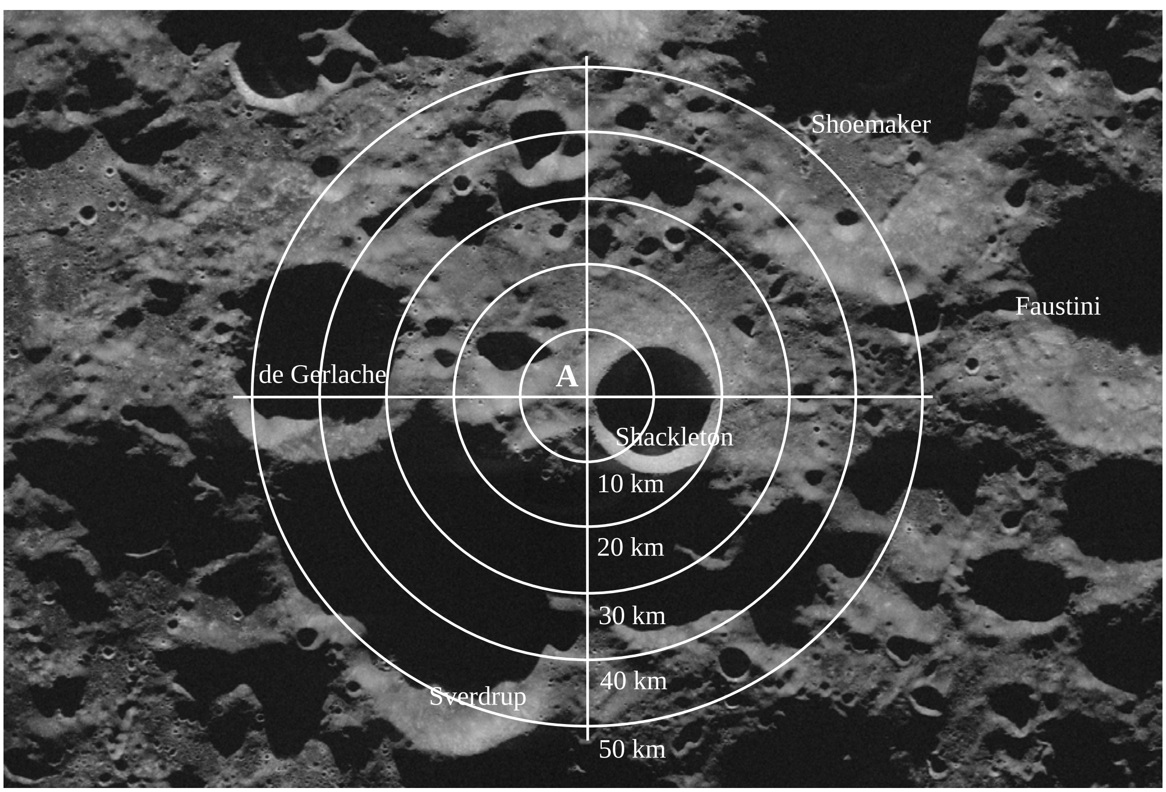

Figure 3: Lunar south pole region
(Cornell University/Smithsonian Institution Image)

1. Astronauts are traveling away from the outpost to study some of the surrounding craters.

   a. If the height of a communication tower at the lunar outpost (Point A in Figure 3) is 50 meters, how far away can they explore and still be within communication range?

   b. Using Table 1, what craters will the astronauts be able to explore?

Table 1: Distance from Outpost to Center of Crater Site

Proposed Site	Distance from Outpost
Shackleton crater	~ 10 km
de Gerlache crater	~ 40 km
Sverdrup crater	~ 45 km
Shoemaker crater	~ 70 km
Faustini crater	~ 80 km

2. In order to increase the line of sight, a higher communication tower must be built. Using what you have learned in question 1, complete Table 2.

Table 2: Various Tower Heights and Related Measurements

Tower Height, ***h*** (m)	Line of Sight Distance, ***d*** (km)	Central Angle Measure, ***θ*** (deg)	Arc Length, ***a*** (km)	Line of Sight Distance per Meter of Tower Height
50				
100				
200				
400				
800				

a. Is there a relationship between line of sight distance and arc length?

b. Is there a relationship between the tower height and central angle measure? Explain your answer.

c. What tower height gives the maximum line of sight distance per meter of tower height?

d. As the tower height increases does the line of sight distance per meter of tower height increase or decrease?

e. As the height of the communication tower doubles in size, does the corresponding line of sight distance double? Why or why not?

f. An 800-meter tower would provide communication to de Gerlache and Sverdrup craters. Approximately how tall would a tower need to be in order to provide communication to Faustini crater? Is either of these heights practical for a communication tower on the Moon? Explain your reasoning.

3. Given what you have discovered in questions 1 and 2, design a plan to provide communication to all five proposed crater sites. Include the type of professions (skills and expertise) you would need in order to successfully implement your plan. Also, make sure to review Figure 3 and decide what lunar features will need to be accounted for in your plan.