Exploring Space Through ALGEBRA

STUDENT EDITION

Geometry and Algebra II

THE LUNAR LANDER – Ascending from the Moon

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.

NASA is developing a new lunar lander, Altair, which will be capable of landing a new generation of explorers on the surface of the Moon by 2020. Altair finds its origins in Arabic and is derived from a phrase that means "the flying one." Altair is the name of the brightest star in the constellation Aquila and is the 12th brightest star in the night sky. In Latin, Aquila means "eagle," reminiscent of the historic Apollo lunar exploration module Neil Armstrong and Buzz Aldrin landed on the moon in 1969.

Similar in design to the Apollo Lunar Excursion Module (LEM), Altair will be much larger and will have the ability to carry four astronauts to the Moon's surface compared to the two-man Apollo LEM. The new lunar lander will also have a much larger crew cabin volume, approximately 12 m^3 (approximately 424 ft^3), compared to the Apollo LEM, 6.65 m^3 (235 ft^3). Figure 1 shows a comparison of the Altair concept and the Apollo LEM.

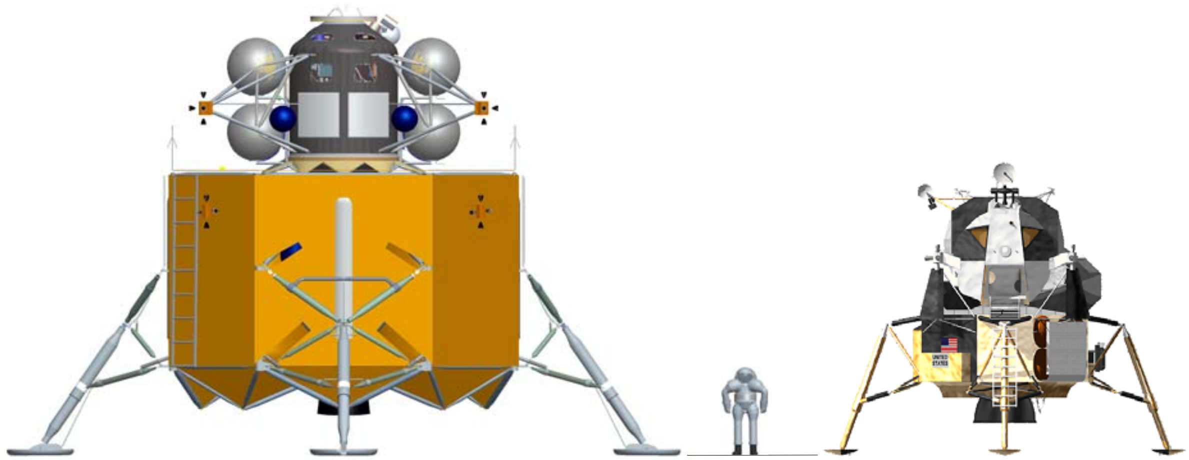

Figure 1: Comparison of the new lunar lander, Altair, (left) (NASA concept) and the Apollo LEM (not to scale)

Altair (See Figure 2) will consist of a descent stage, an ascent stage, and a large cargo volume that can be occupied by habitation modules or cargo. The descent stage provides the capability to get into lunar orbit and to perform a lunar landing. It also serves as the launch platform for the ascent stage and as a "flat bed truck" that will transport large cargo to the lunar surface. The ascent stage functions as the flight deck/crew cabin for landing on the lunar surface. It will provide life support for a limited number of days of surface stay, and will allow the crew to ascend back to lunar orbit.

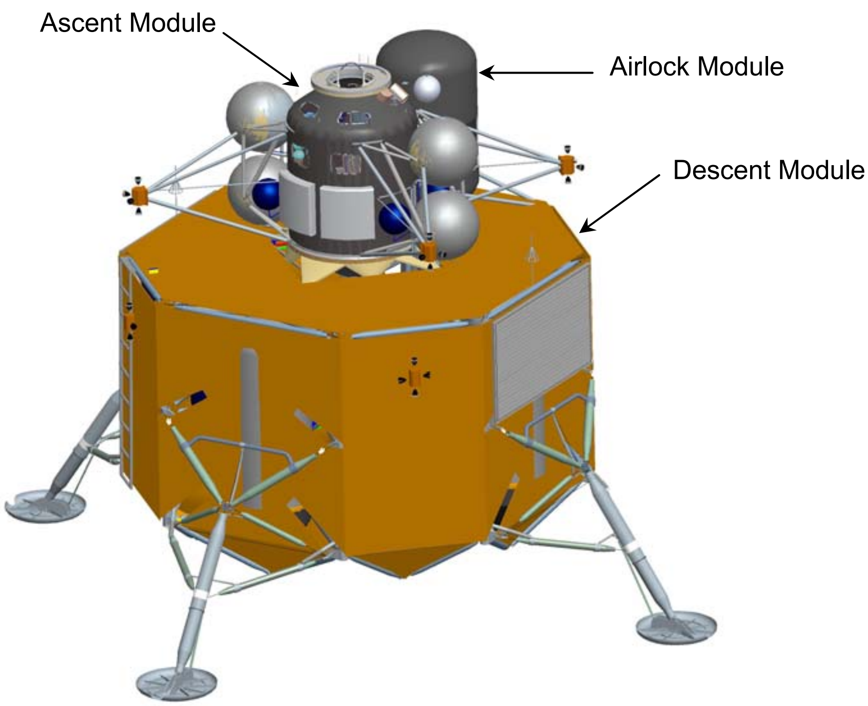

Figure 2: Altair lunar lander (NASA Concept)

During the Apollo era, astronauts could only stay on the lunar surface for a maximum of three days. This time, NASA plans to stay longer. By going to the Moon for extended periods of time, astronauts will search for resources and learn how to work safely in a harsh and unfamiliar environment – stepping stones to future exploration. As currently envisioned, four person crews will stay on the Moon for several days at a time. Altair will provide life support and a base for lunar surface exploration missions. These crews will incrementally build a lunar outpost with power, supplies, rovers and living quarters. Once the outpost is operational, the missions will be extended to two weeks, then two months and ultimately 180 days. Over the first decade of lunar habitation, space explorers will practice the techniques and skills needed for the eventual journey to Mars.

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

Problem

Suppose you are a NASA propulsion engineer working on Altair's ascent stage. Based on outside forces of the lunar environment acting on Altair as it ascends vertically, you have determined the equation of motion for the vehicle to be $\boldsymbol{y(t)=0.683t^2}$, where the height, ***y,*** is measured in meters and the time, ***t,*** is measured in seconds. The quantity, 0683 m/s^2, is the launch acceleration required by the ascent stage to escape the Moon's gravity. Near a lunar outpost on the Moon, an astronaut with a camera at ground level and 1000 m from the base of Altair is filming the lift-off of the ascent of the vehicle. See Figure 3. Set your calculator mode to degrees before completing the following questions. Round your answers to the nearest whole number.

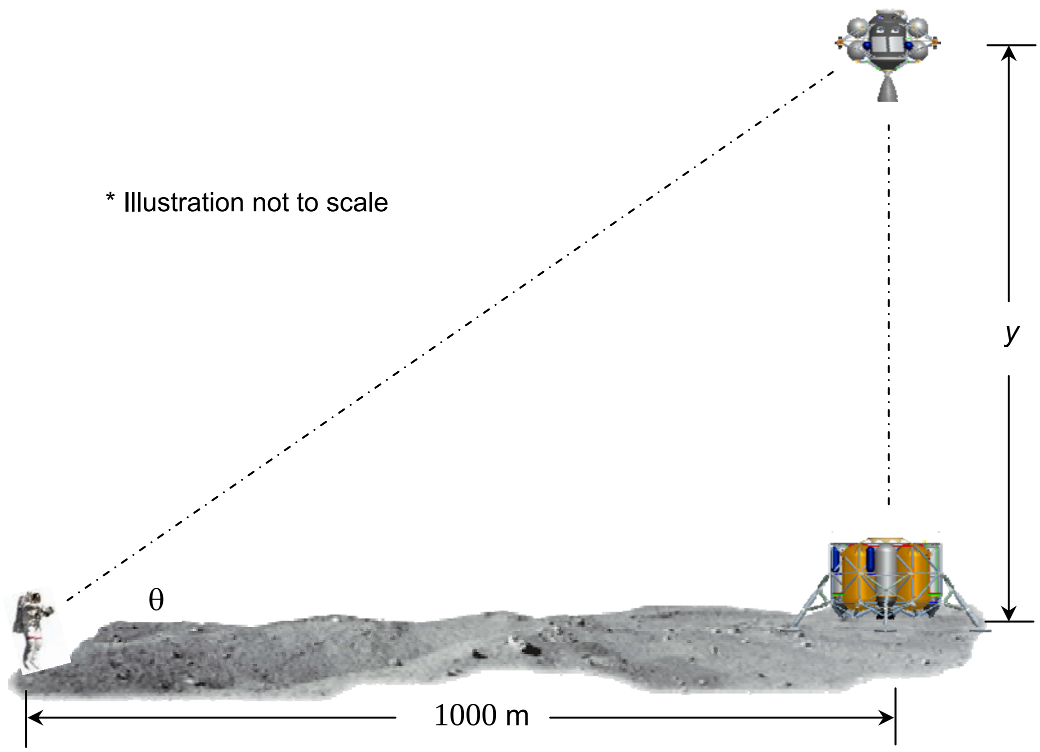

Figure 3: Problem Diagram

1. Find the height of the ascent stage vehicle 10 seconds after lift-off.

2. Find the angle of elevation of the camera 10 seconds after lift-off.

3. How much time has elapsed when the vehicle is 100 m above the surface? What is the angle of elevation of the camera at this time?

4. What is the height of the vehicle when the angle of elevation is 20°? How much time has elapsed at this point?

5. What is the angle of elevation when the ascent stage is 2000 m above the surface? When does this occur?

6. Write an equation to describe the angle of elevation of the camera, θ, in terms of y, the height of the vehicle.

7. Write an equation describing the angle of elevation, θ, in terms of t, the time elapsed since lift-off.

8. Graph the equation describing the angle of elevation, θ, in terms of t and the equation $y = 90°$ on your graphing calculator. Set your window settings to show time up to 250 seconds and angle measure up to 100°. What is happening to the angle of elevation as time elapses? Does the angle ever reach 90°? Explain why this happens.