MATH AND SCIENCE @ WORK

AP* PHYSICS Student Edition

*AP is a trademark owned by the College Board, which was not involved in the production of, and does not endorse, this product

LUNAR SURFACE INSTRUMENTATION: Part II

Background

This problem builds from the *Math and Science @ Work Lunar Surface Instrumentation* problem. Students should complete the Lunar Surface Instrumentation problem first, in order to better understand the importance of extrahabitat activities (EHA) during long-duration human missions to the surface of the Moon and other planetary bodies.

Problem Situation

NASA hopes to soon execute long-duration missions to the surface of the Moon and other planetary bodies. You are a member of the mission planning team at NASA Johnson Space Center. Your team needs to develop a plan for three instruments located around a polar region lunar outpost that need to be serviced by an astronaut resident at that lunar outpost. This servicing will be accomplished by an astronaut putting on a space suit to walk around the lunar surface in an extrahabitat activity or EHA.

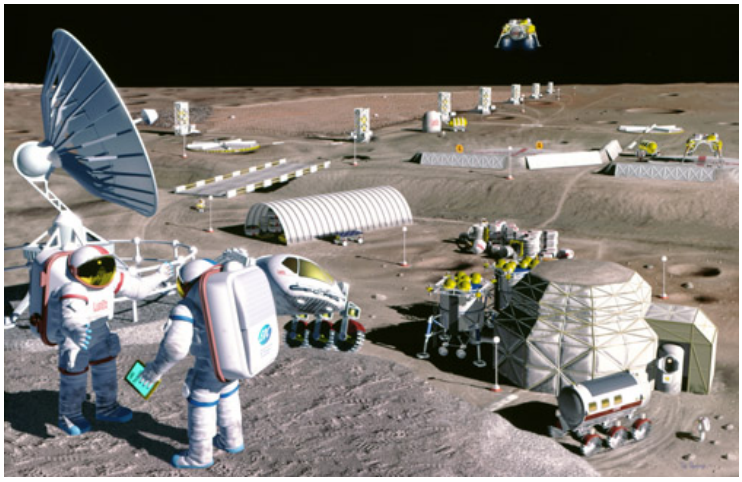

Figure 1: Astronauts on an EHA near a Lunar outpost (NASA concept)

Assuming a Cartesian coordinate system where the positive *x*-axis is east and the positive *y*-axis is north, relative to the habitat airlock at the origin, the three instruments are located:

1. 200 m, southwest,
2. 175 m, 15º north of west, and
3. 150 m, 30º west of north.

Constraints

The constraints applicable to developing the plan are as follows:

1. An astronaut can carry a maximum of 25 kg when walking.
2. An astronaut can use a lunar surface transporter (a remote controlled, battery-powered "cart" with wheels) with a maximum load of 100 kg on it. The astronaut will walk alongside the transporter and therefore, cannot carry anything while controlling the transporter.
3. An astronaut can walk 6 kilometers per hour (km/h) when unburdened, 4 km/h when carrying a load, and 3 km/p when controlling a lunar surface transporter (loaded or unloaded).
4. During such an activity, astronauts will carry their own life support system and supplies (e.g. water and breathable air) with total capacity for 5 hours.
5. When an astronaut returns to the habitat, they must have a minimum reserve life support supplies for 1 hour remaining in their life support system.
6. The equipment to be installed at the three instruments is the following:
    a. One 20 kg sample cell at Instrument #1,
    b. Two 15 kg lens component at Instrument #2, and
    c. One 25 kg camera at Instrument #3.
7. The installation times involved at the three instruments are as follows:
    a. 20 minutes to install the sample cell at Instrument #1,
    b. 15 minutes to install each lens component at Instrument #2, and
    c. 45 minutes to install the camera at Instrument #3.

Mission Planning

As a member of that mission planning team, your assignment is to examine two approaches for the astronaut's EHA. The primary selection criterion is the amount of life support supplies available at the end of the activities and whether that amount meets the constraint. The two EHA approaches are:

1. Use a lunar surface transporter to carry all the equipment for the three instruments; or
2. Carry one set of equipment at a time to each of the three instruments from the habitat airlock.

Problem

A. Sketch the instrument locations with the origin at the airlock.

B. Using the sketch from Question A and the provided information:

   I. Determine the instruments' locations (x, y) from the airlock. Round your answers to the nearest tenth of a meter.

   II. Determine the astronaut's displacement (using unit-vector notation) from the airlock when she is standing at each instrument. Round your answer to the nearest tenth of a meter.

C. Subject to the constraints, determine the total distance the astronaut would walk for each of the two EHA approaches to service the instruments. Round your answer to the nearest tenth of a meter.

   I. Utilizing a lunar surface transporter to carry all equipment.

   II. Carrying loads to each instrument.

D. Subject to the constraints, determine the time it would take for the astronaut to travel and service the instruments for each of the two EHA approaches. Round your answer to the nearest tenth of a minute.

   I. Utilizing a lunar surface transporter to carry all equipment.

   II. Carrying loads to each instrument without use of lunar surface transporter.

E. Explain which approach is more efficient in terms of:

   I. The distance the astronaut walks.

   II. The amount of reserve time remaining in the astronaut's life support system when she arrives back at the airlock.