MATH AND SCIENCE @ WORK

AP* PHYSICS Educator Edition

LUNAR SURFACE INSTRUMENTATION: Part II

Instructional Objectives

Students will
- add, subtract, and resolve displacement using unit-vector notation;
- evaluate two approaches, apply a set of constraints, and choose the best alternative to the problem.

Degree of Difficulty

This problem is a straightforward application of vector concepts.

- For the average AP Physics student, the problem may be moderately difficult.

Background

This problem is part of a series of problems that apply math and science principles to human space exploration at NASA.

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.

AP Course Topics

Newtonian Mechanics

- Kinematics (including vectors, vector algebra, components of vectors, coordinate systems, displacement, velocity, and acceleration)
    - o Motion in one dimension

NSES Science Standards

Science and Technology

- Abilities of Technological Design

History and Nature of Science

- Science as a Human Endeavour

Grade Level
11-12

Key Topic
Vector Addition

Degree of Difficulty
Physics B, C: Moderate

Teacher Prep Time
5 minutes

Problem Duration
30 minutes

Technology
- TI-Nspire™ Learning Handhelds
- TI-Nspire document: *Instrumentation2.tns*

AP Course Topics
Newtonian Mechanics:
- Kinematics

NSES
Science Standards
- Science and Technology
- History and Nature of Science

Problem Situation

Students are given the following problem information within the TI-Nspire document, Instrumentation2.tns. The questions are embedded within the TI-Nspire document.

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.

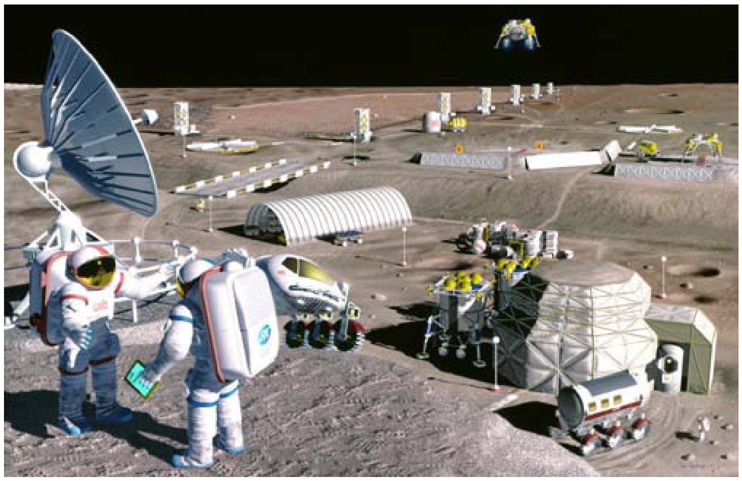


Figure 1: Astronauts on an EHA near a lunar outpost (NASA concept)

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 kilograms (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/h 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 astronauts return 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:

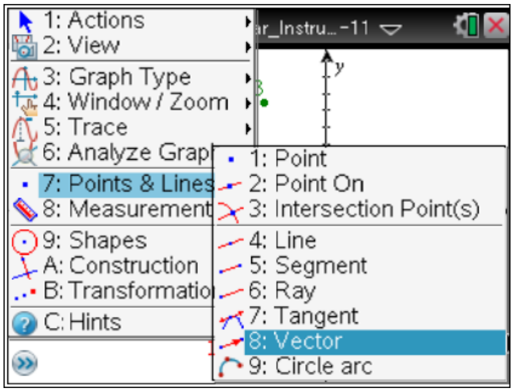
1. Use a lunar surface transporter to carry all the equipment for the three instruments; or

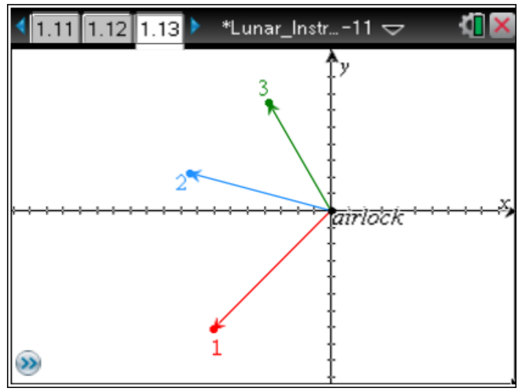
2. Carry one set of equipment at a time to each of the three instruments from the habitat airlock.

Problem and Solution Key (One Approach)

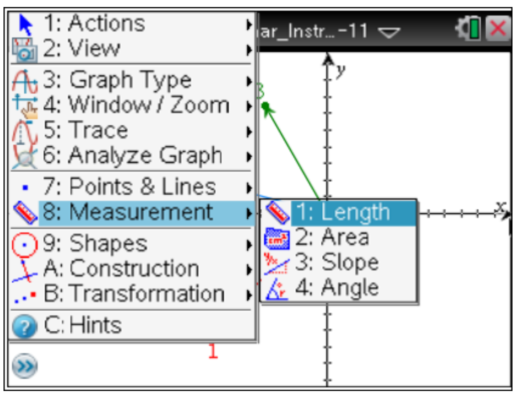
A. Sketch the instrument locations with the origin at the airlock. To sketch this on TI-Nspire page 1.13, use the vector tool to draw vectors to each instrument and the measurement tool to show the location of each vector.

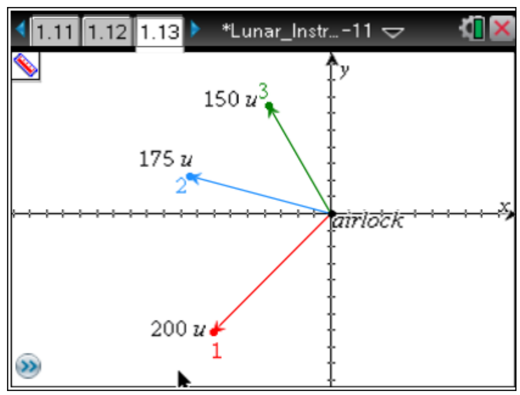
*If students are new to using the TI-Nspire, they may need some guidance. Start on page 1.13 by pressing **menu** and then selecting **Points & Lines > Vector** as shown in the screen shot below. They can then create a vector by selecting the starting point (airlock) and then dragging the vector to the ending point (the instrument). To change the color of a vector, place the pointer on the vector, press **ctrl** and **menu**, select **Color > Line Color**, and then select the desired color.*



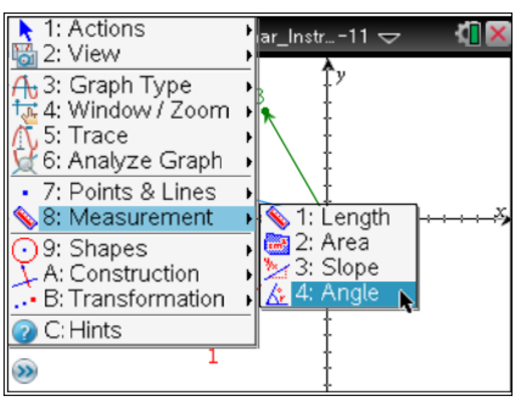


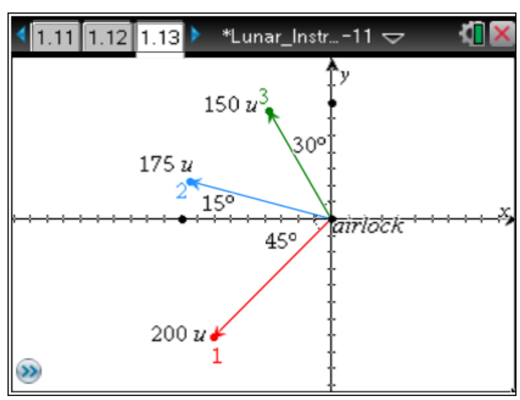
*To show the location of each instrument, first find the distance using the measurement tool. Press **menu** and select **Measurement > Length**. Move the pointer to a vector, click the center of the touchpad, move the text to the desired location, and click the center of the touchpad again.*





*To also show the angles on the diagram, press **menu** and select **Measurement > Angle**. The angle is found by clicking three points that define the angle. For instrument 1 (southwest or 45° south of west), first select a point on the negative x-axis (west), then select the origin, then select the point at instrument 1. Press esc to exit the angle mode and move the text to the desired location.*



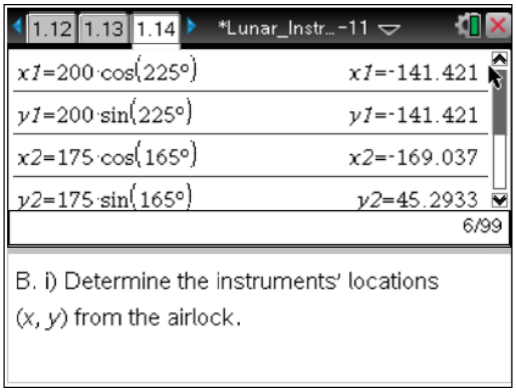


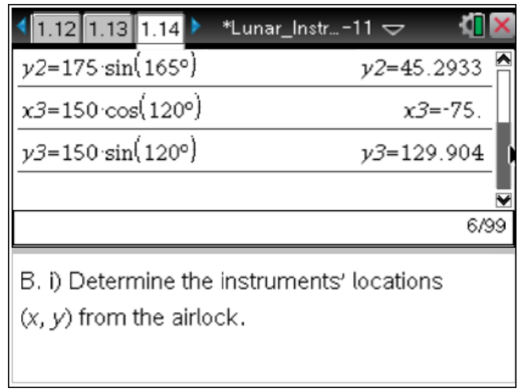
An alternative to having students sketch in the Nspire is to have them create the sketch on paper. This may be advantageous if there is little time and students are not very familiar with the technology.

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

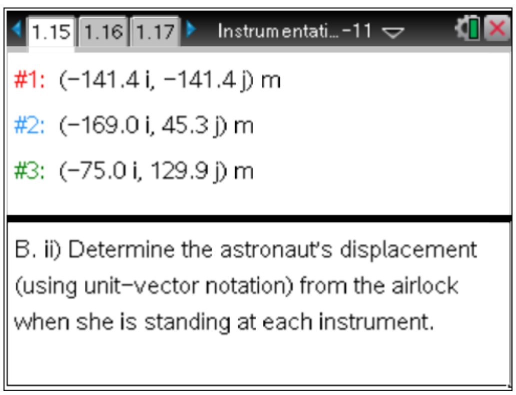
I. Determine the instruments' locations (x, y) from the airlock.

Students should find the (x, y) components of each vector in order to find the position of the instruments.





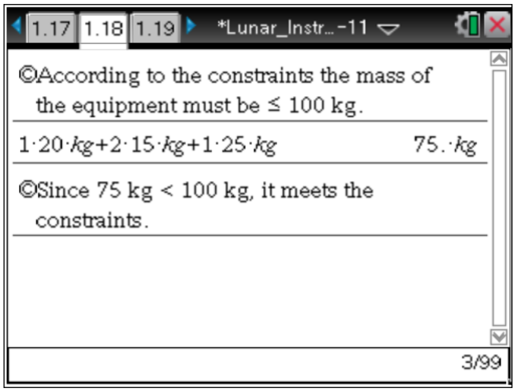
II. Determine the astronaut's displacement (using unit-vector notation) from the airlock when she is standing at each instrument.

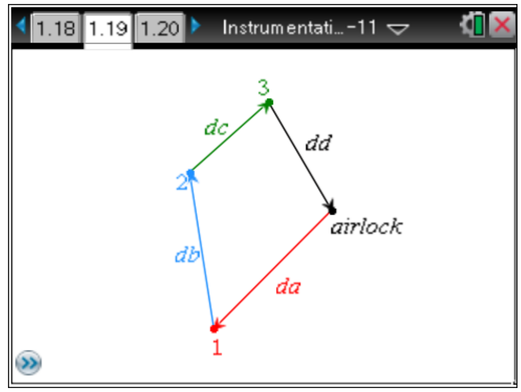


C. Subject to the constraints, determine the total distance the astronaut would walk for each of the two EHA approaches to service the instruments.

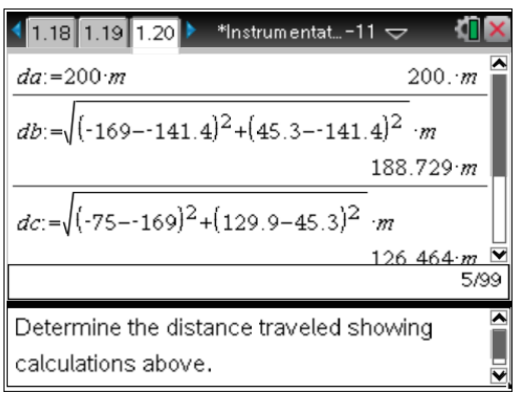
I. Utilizing a lunar surface transporter to carry all equipment.

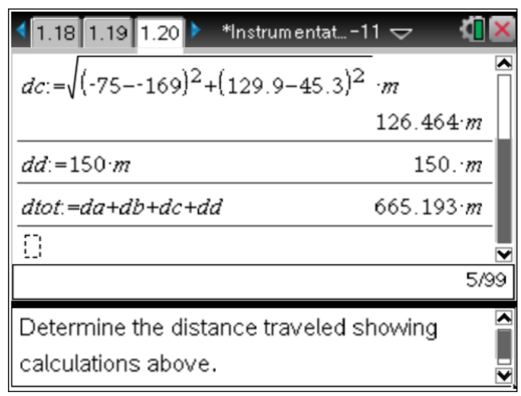
*First verify that the constraints for utilizing the lunar surface transporter are met. Then sketch the path taken on page 1.19. Draw the vectors then label each leg of the trip by selecting the vector, pressing **ctrl** and **menu**, and selecting **Label**.*



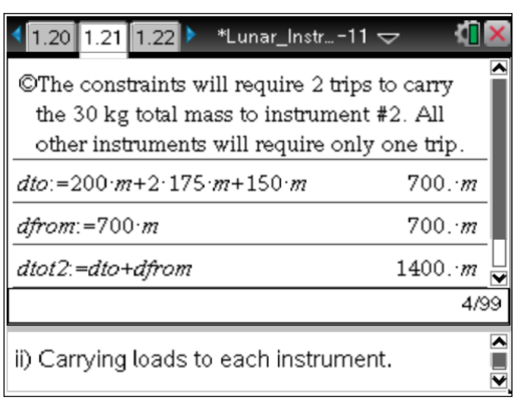


Determine the length of each segment, and then find the summation to determine total length.



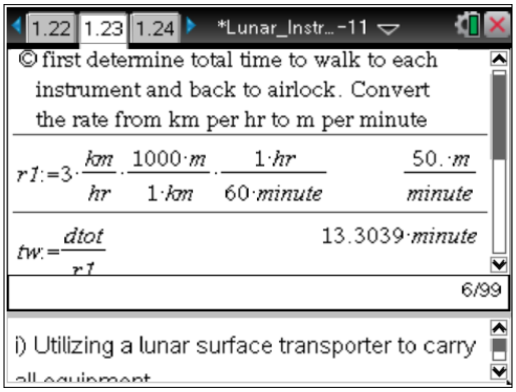


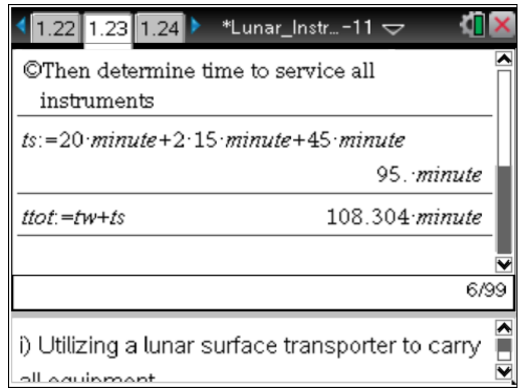
II. Carrying loads to each instrument without use of lunar surface transporter.



D. Subject to the constraints, determine the time (in minutes) it would take for the astronaut to travel and service the instruments for each of the two EHA approaches.

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





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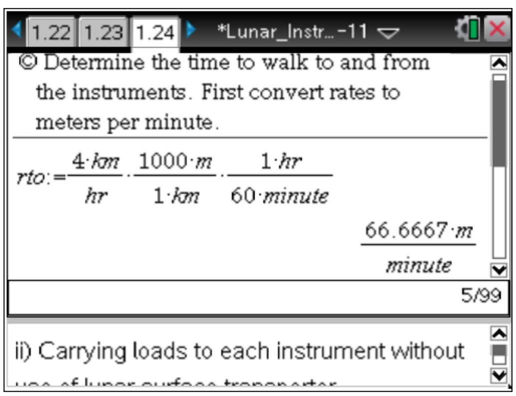

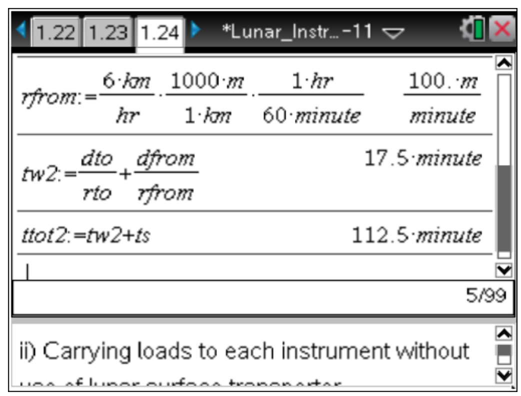

E. Explain which approach is more efficient in terms of:

I. The distance the astronaut walks.

Using the lunar surface transporter, the astronaut would walk 734.8 m less than if she carried the loads to each instrument without it.

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

Using the lunar surface transporter is 4.2 minutes faster and would leave more reserve time remaining in the astronaut's life support system.

Scoring Guide

Suggested 15 points total to be given.

Question		Distribution of points
A	*2 points*	1 point for a sketch in the correct orientation 1 point for correct angle measurements shown on sketch
B	*3 points*	1 point for correctly using cosine function to find the *x*-coordinates of the instruments 1 point for correctly using the sine function to find the *y*-coordinates of the instruments 1 point for correct conversion to vector notation for the three instrument locations
C	*5 points*	1 point for recognizing that the constraints for mass will be met using the lunar surface transporter 1 point for correct use of distance formula or Pythagorean theorem to find the distance from instrument #1 to #2 and from #2 to #3 1 point for finding the correct total distance using the lunar surface transporter 1 point for recognizing that the constraints will require two trips to instrument #2 when carrying the loads without use of lunar surface transporter 1 point for finding total distance traveled when not using lunar surface transporter
D	*3 points*	1 point for correctly finding total time to travel from airlock to each instrument and back to the airlock when using lunar surface transporter 1 point for correctly finding the time to service each instrument 1 point for correctly finding the total time to travel to and from the instruments when not using the lunar surface transporter
E	*2 points*	1 point for correctly identifying use of the lunar surface transporter as the more efficient approach in terms of distance the astronaut walks 1 point for correctly identifying use of the lunar surface transporter as the more efficient approach in terms of the amount of reserve time remaining in life support system

Contributors

Thanks to the subject matter experts for their contributions in developing this problem:

NASA Expert

NASA Glenn Research Center

Richard DeLombard
Exploration Outreach and Education Project Manager
Space Flight Systems Directorate

Problem Development

NASA Langley Research Center

Chris Giersch
Communications and Education Lead
Exploration and Flight Projects Directorate

NASA Johnson Space Center

Natalee Lloyd
Education Specialist
Human Research Program Education and Outreach

Monica Trevathan
Education Specialist
Human Research Program Education and Outreach

Traci Knight
Graphics Specialist
Human Research Program Education and Outreach

National Institute of Aerospace

Norman "Storm" Robinson, III
Education Specialist

Troy City School District

Jennifer Gottlieb
Physics Teacher
Troy Athens High School

Texas Instruments

Todd Morstein
Texas Instruments T^3 (Teachers Teaching with Technology™) National Instructor