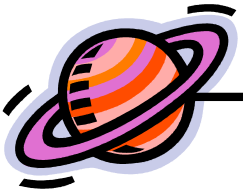


Distance = Rate x Time

Middle grades

Lesson Summary
Students practice using the equation distance = rate x time using trajectory data from the Apollo 11 lunar landing mission.

Prior Knowledge & Skills
- Basic equations and arithmetic

AAAS Science Benchmarks
The Nature of Technology
Design and systems
Technology and science

NSES Science Standards
- **Physical science:** Motions and forces

NCTM Mathematics Standards
- **Algebra**: Use mathematical models to represent and understand quantitative relationships

Teaching Time: Two 45-minute periods, 1 or 2 days apart

Materials
Each group needs:
- Worksheet

Advanced Planning
Preparation Time: 20
1. Copy worksheets
2. Review lesson

Why Do We Care?
The Galileo spacecraft, launched in 1989, arrived at Jupiter in 1995 and spent more than 8 years studying Jupiter and its satellites. In 2003, Galileo was deliberately plunged into Jupiter's atmosphere, where it was crushed by Jupiter's high pressure.
In the famous Apollo 11 mission, Neil Armstrong and Buzz Aldrin became the first humans to set foot on the moon. The spent 21 hours on the moon before returning to their Command Module, 46 pounds of moon rocks in tow.

Source: Eileen V. Ryan
NOAO/ Planetary Sciences, University of Arizona, Tucson AZ.

LASP
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO AT BOULDER

DISTANCE = RATE x TIME

Concepts:

- units conversion
- geometry
- division and multiplication
- graphing
- analyzing data
- using equations

INTRODUCTION

When we think of how fast we're going (or the rate at which we're traveling) in a car, we usually express it in "miles per hour". This rate (miles/hr) is really reflecting the average distance that we've gone in the time it takes to travel that distance. For example, a car that travels 60 miles in 1 hour is traveling at a rate of 60 miles/hr. Alternately, a car that has a speed of 60 miles/hr will have traveled 60 miles in 1 hour. At this rate, in 2 hours it will have traveled a distance of 120 miles.

Therefore, given some basic information, like how fast an object is going (its speed or rate) and how long it took to get to where it is now (time), it is possible to determine the distance that object has traveled. This concept can be expressed as an equation that has the following form:

$$D = R \times T$$

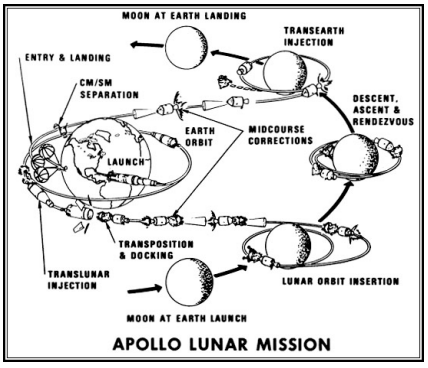
where D is the distance, R is the rate or speed, and T is the elapsed time. This basic idea can be applied to many situations. In the following exercises, you will calculate the distance to the moon (TASK A), and the speed or rate of the Galileo Spacecraft on its way to Jupiter (TASK B).

BACKGROUND: Units
For the calculations we will perform in this lesson, we will be using the metric system. That is, we'll express distance in terms of kilometers and *not* miles . Some useful relationships:

- 1 mile = 5280 feet
- 1 mile = 1.61 kilometer
- 1 kilometer = 0.62 miles
- 1 hour = 60 minutes
- 1 minute = 60 seconds
- 1 hour = 60 minutes/hour x 60 seconds/minute = 3600 seconds
- 24 hours = 1 day

TASK A: Distance to the Moon (Apollo Data)

Apollo 11: Lunar Landing Mission



The Apollo 11 spacecraft was launched from Cape Kennedy at 13:31:01 GMT on July 16, 1969. After 2 hr and 33 min in Earth orbit, the S-IVB rocket engine was reignited for acceleration of the spacecraft to the velocity required to escape Earth's gravity. Although at times the spacecraft reached speeds near 40,000 km/hr, the average speed was about 5500 km/hr .

Lunar-orbit insertion began at 75:50 (75 hours and 50 minutes) ground elapsed time (GET). The spacecraft was placed in an elliptical orbit (61 by 169 nautical miles), inclined 1.25 degrees to the lunar equatorial plane. At 80:12 GET, the service module propulsion system was reignited, and the orbit was made nearly circular (66 by 54 nautical miles) above the surface of the Moon. Each orbit took two hours.

The lunar module (LM), with Astronauts Armstrong and Aldrin aboard, was undocked from the command-service module (CSM) at 100:14 GET, following a

thorough check of all the LM systems. At 101:36 GET, the LM descent engine was fired for approximately 29 seconds, and the descent to the lunar surface began. At 102:33 GET, the LM descent engine was started for the last time and burned until touchdown on the lunar surface. Eagle landed on the Moon 102 hr, 45 min and 40 sec after launch.

ACTIVITIES: Using the above information and our D = R x T equation, can you calculate the distance to the moon?

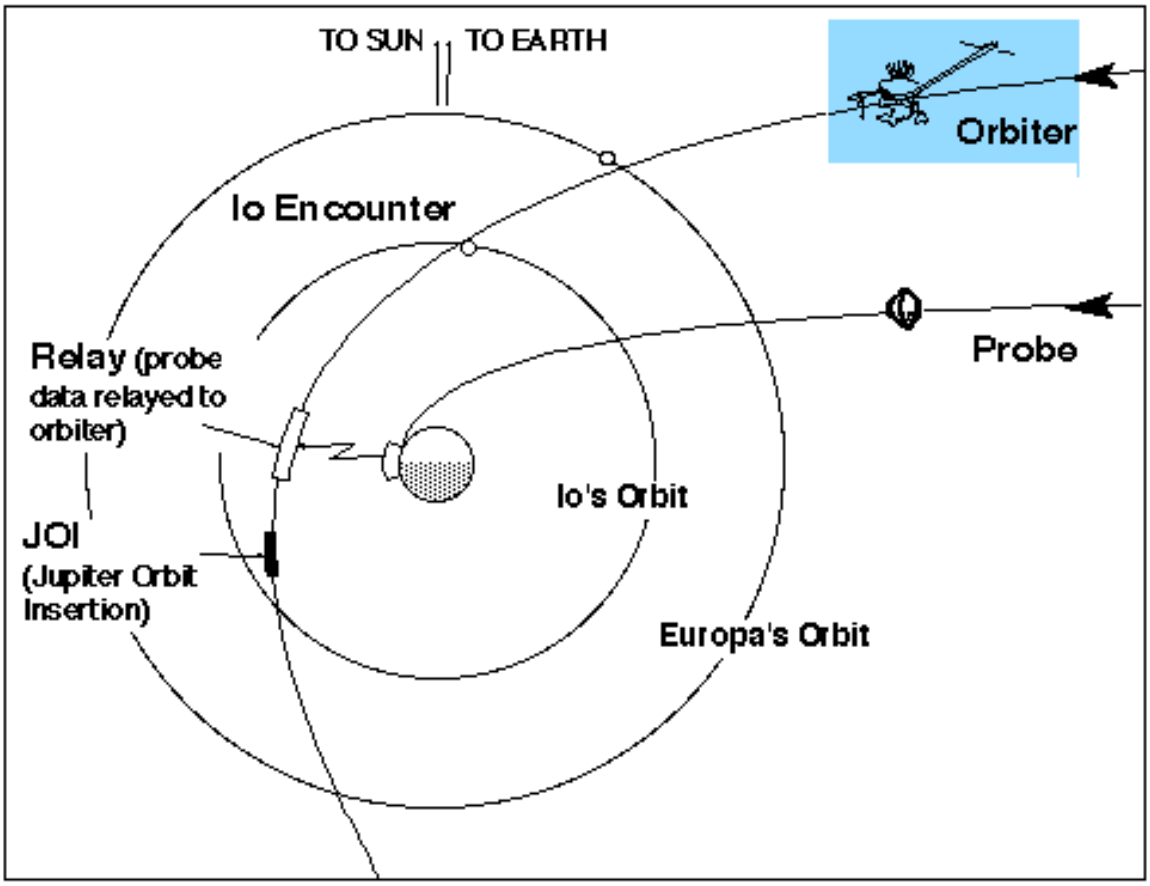
- The Elapsed Time = (75 hrs 50 min)- (2 hrs 33 min) = 73 hrs 27 min
- average speed (Rate) = 5500 km/hr

ANSWER :

The moon is actually 384,400 km away from the earth . If you multiplied the rate (5500 km/hr) by the time (73.45 hours), your answer should be = 403,975 km which is pretty close to the actual lunar distance. We didn't get the *exact* distance because the Apollo spacecraft speeds up and slows down on the course of its journey to the moon, and we had to *approximate* the rate with an *average* speed.

TASK B: Galileo Spacecraft Navigation

Like Voyager and some other previous interplanetary missions, Galileo used planetary gravitational fields at certain stages for extra propulsion (called a "gravity-assist"). The spacecraft used the gravitational fields of Venus and Earth to pick up enough velocity to get to Jupiter. The total trip time was longer than six years.



Path of Spacecraft

On arrival day (December 7, 1995), the Orbiter skims 1,000 km above Io, picking up a gravity-assist, and then subsequently flies over the descending Probe so that the Probe can relay its data to the Orbiter. About an hour after the Relay, the engine will burn fuel for nearly an hour to place Galileo into orbit around Jupiter.

Galileo Spacecraft Navigation

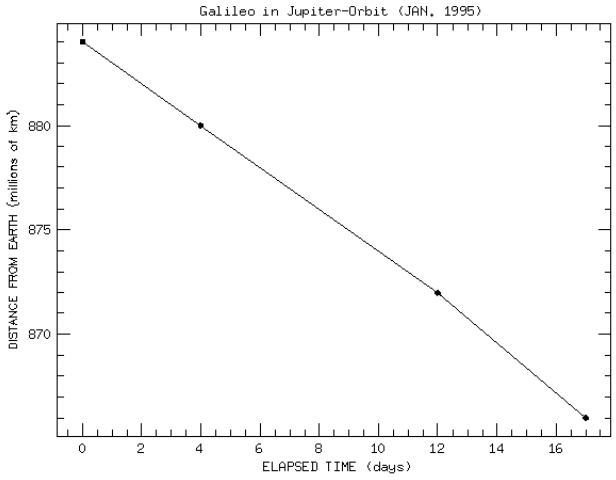
The following table lists statistical information for Galileo in January, 1995. Remember, at this point in time, the Galileo Spacecraft has reached its destination (It arrived in December.) and is in a stable orbit around Jupiter.

	Date	Elapsed Time (hours)	Distance from the Earth (millions of km)	Distance Traveled (millions of km)	Rate (km/sec)
Starting Point	1-1-95	0	883.7	---	---
Position 1	1-5-95	96	880.4	3.3	9.6
Position 2	1-13-95	288	872.2	11.5	11.1
Position 3	1-18-95	408	866.1	17.7	---
Position 4	1-25-95	576	856.3	27.4	13.2
Position 5	1-31-95	720	846.8	36.9	---

ACTIVITIES: Using the above table, which tracks the distance of the Galileo Spacecraft from the earth in January of last year, make two graphs:

- The Elapsed Time (Convert hours to days.) *vs.* Distance from the Earth, and
- the Date *vs.* the Distance Traveled.

Sample Plot:



Interpretation

In January 1995, the Galileo Spacecraft was circling (in orbit) around Jupiter.

Q. Looking at your first graph, is Galileo traveling *away from* or *towards the Earth*?

A: It is traveling *towards the earth*, since the Distance from the Earth is getting smaller as time progresses

Q: What is the total distance Galileo has traveled in the month of January?

A: 36900000 km (or 36.9 *million km's*)

Q: What trends do you notice in looking at your graph of Date *vs.* the Distance Traveled?

A: *The distance traveled is not constant, indicating that the spacecraft is speeding up.*

Q: Calculate the Rate for Positions 3 and 5 in the above table.

A: *12 km/sec* and *14.2 km/sec*

HINT: Since rate is distance per time, divide the Distance traveled by the Elapsed Time. Remember to convert *hours* to seconds , and that the values in the table are *millions* of km's.

Sample Calculation, Position 2: How was the rate for *Position 2* in the table calculated? Since distance divided by time is rate, we use the Distance Traveled and divide by Elapsed Time : Rate = (11500000 km) / [(288 hours) x (60 min/hr) x (60sec/min)] = 11.1 km/sec

This module was written by Eileen V. Ryan
NOAO/ Planetary Sciences, University of Arizona, Tucson AZ.

Student Worksheet

In January 1995, the Galileo Spacecraft was circling (in orbit) around Jupiter.

Q. Looking at your first graph, is Galileo traveling *away from* or *towards the Earth*?

_____

Q: What is the total distance Galileo has traveled in the month of January?

_____

Q: What trends do you notice in looking at your graph of Date *vs.* the Distance Traveled?

_____

_____

Q: Calculate the Rate for Positions 3 and 5 in the above table.

_____

_____

HINT: Since rate is distance per time, divide the Distance traveled by the Elapsed Time. Remember to convert *hours* to seconds , and that the values in the table are *millions* of km's.