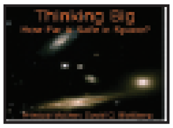
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

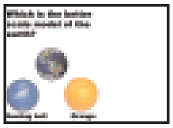
Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



Slide 1: Title



Slide 2: Orange vs. Bowling Ball

HOOK: Toss an orange from a hidden position to a student who is paying attention.

Discussion: Look carefully at the orange, feel its rough skin: Would the orange make a good scale model for the earth? What would be a better model for the earth: the orange, with its rough skin, or a smooth bowling ball?

The answer will be discussed in depth later in the lesson.

Slide 3: Moon Landing

Q. Besides the earth, what other bodies in the solar system has humankind visited?

A. Humans landed on the moon on July 21, 1969.

Slide 4: Mars

Discussion: Mars is much farther away from the earth. Do you think it is a realistic possibility to get there safely?

Within the next two decades, NASA plans to send a crewed mission to Mars. It will be the longest space journey ever undertaken by humans. It will take three years, round trip. To send humans so far into space for so long, scientists will have to work with some very large numbers. The amount of fuel and money spent, the distance traveled, the speed of the air-craft and the time to send and receive communication signals will require scientists to think very big.

By the time the mission is ready to be launched, students currently in high school could be eligible to travel in space or work on space related research. To understand the science behind space travel, it is important to be able to work with extremely large numbers. To do this, we will use several mathematical concepts, including Powers of Ten notation.

Q. What is Scientific Notation, or "Powers of Ten?"

A. A method of writing very large numbers in a compact and understandable way.

We have already been to the moon, about 384,000 kilometers away from earth.

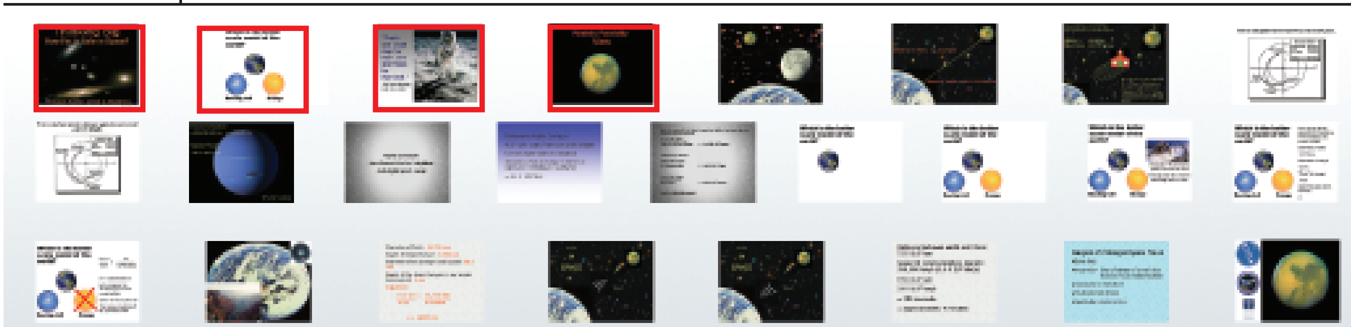
Q. How much farther away is Mars? By using Powers of Ten, we can find out a rough estimate of how much farther away Mars is from earth than the moon.

Distance to the moon: 384,000 km or 3.84×10^{5} km

Distance to Mars (at closest): 75,000,000 km 7.5×10^{7} km

To get a rough approximation of how much farther away Mars is, we subtract exponents.

$7-5 = 2$. Mars is 2 powers of ten farther from earth than the moon.



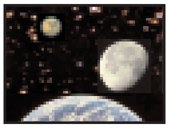
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content

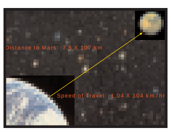


Slide 5: Mars and the Moon
Q. What is 2 powers of ten equal to?
A. 100
Mars is roughly 100 times farther from earth than the moon.

*Mars is actually closer to 200 times the distance to the moon, but the essential concept here is the difference in orders of magnitude, or powers of ten. Mars is 2 powers of ten farther from earth. The distance to the moon is measured in the hundreds of thousands of kilometers; the distance to mars is meaasured in millions of kilometers.
Q. More Exact Approximation: How many times would we have to travel to the moon to equal the distance we would have to travel to get to Mars.

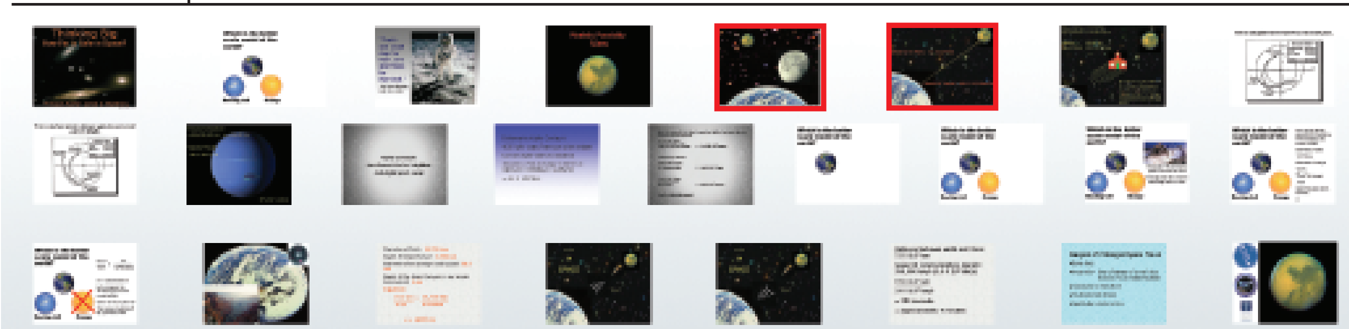
We use division: $\frac{\text{Distance to Mars}}{\text{Distance to Moon}} \quad \frac{7.5 \times 10^7}{3.84 \times 10^5}$

Using a calculator: the answer is 195.3.
We would have to travel to the moon 195 times to equal one trip (one way) to mars.



Slide 6: Speed of Travel - Mission Planning
During their respective orbits around the sun, the earth and Mars are 75 million kilometers away at their closest.
Discussion: How long will it take for a crewed spacecraft to reach Mars? How long will the round trip be?
Q. How long will it take to reach mars?
Distance to Mars: 7.5×10^7
Speed of travel: 1.04×10^4 km/hour
Discussion: Before we figure this out, do you think traveling in a straight line is the best way to go to Mars?
Answer: The answer is no. There are no straight lines in space. A space craft launched to Mars, or to any destination in the solar system, does not travel there in a straight line. When it leaves Earth, the space craft is still in orbit around the Sun and so its flight path is a curved trajectory. In the case of a mission to Mars, the curve of the trajectory is aimed at a place along Mars' orbit, where Mars will be when space craft arrives.
(This answer comes courtesy of Bruce Thompson of NASA in response to a question posed on http://quest.arc.nasa.gov/)
*There are more reasons why a craft traveling between earth and Mars would take an arced path. What might these reasons be? Try looking for the answer on http://quest.arc.nasa.gov

Nasa will launch at least two "packages" into space years before the Mars mission. The crewed space craft will rendezvous with these packages for refueling and filling up on supplies on the way to the red planet.



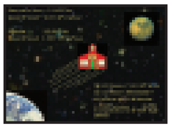
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



Slide 7: Time of Travel to Mars

Imagine the classroom is hurtling towards Mars at the same speed NASA will send astronauts to Mars in the future. Imagine that you have to sit in class that entire time.

Q. How many forty minute class periods would a student have to sit through to equal the time it will take to get to Mars?

Distance to Mars = 7.5×10^{7} km

Speed of travel = 1.0×10^{4} km/hour

$$\frac{\text{Distance}}{\text{Speed of travel}} \qquad \frac{7.5 \times 10^{7}\ \text{km}}{1.04 \times 10^{4}\ \text{km/hour}}$$

A. 7211.5 hours or 7.2×10^{3} hours

*(To figure out how many days, divide by 24.

Answer: 300 days

(This is an approximation. In the actual trip planning, there are numerous variables that make travel time closer to 225 days in one plan and 150 days in another plan.))

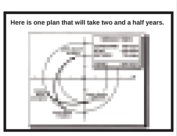
Q. Using this value, how many class periods would a student sit through to equal the time spent traveling to Mars?

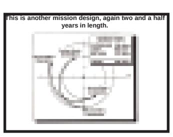
Find the minutes:

7211.5 hours X 60 minutes = 432,690 or 4.3×10^{5} minutes

Convert to forty minute periods:

A. 4.3×10^{5} minutes = 10,750 class periods or 1.07×10^{4} class periods.





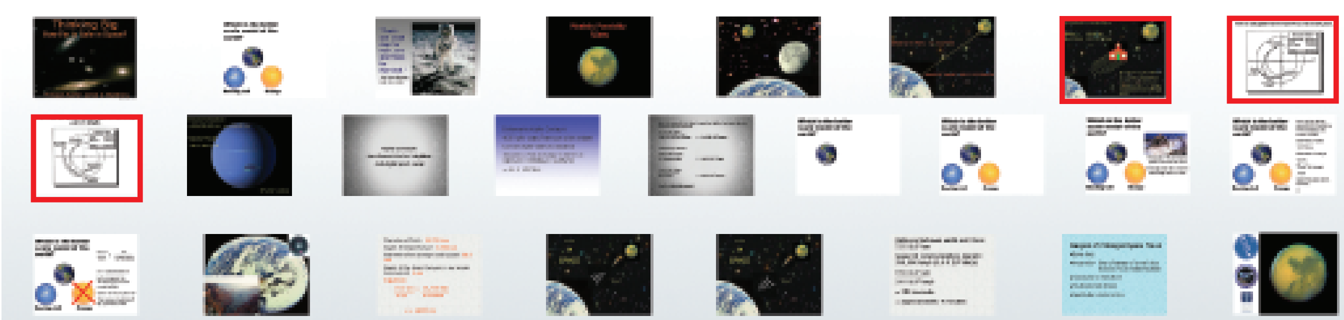
Slides 8-9: Danger in Space

Discussion: What are some risks posed by such a long journey? Remember that the astronauts have to make it back to earth! So actual trip time will be much longer.

The total planned time for the mission is about nine hundred days, including round trip travel and time spent on Mars.

Discussion: What problem might arise for astronauts spending so much time together in a small spacecraft?

Answer: Psychosocial stress; interpersonal problems; personality clashes; command structure; authority issues.



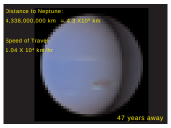
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



*Traveling Farther Away?
Slide 10: Travel to Neptune
Is it realistic to send humans to Neptune?

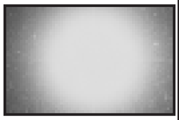
Distance to Neptune from earth:
4,338,000,000 km = 4.3×10^9 km
Speed of travel (we assume it would be the same):
1.04×10^4 km/hour

Travel time: $\frac{4.3 \times 10^9 \text{ km}}{1.04 \times 10^4 \text{ km/hour}}$

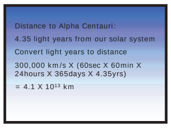
Answer: 413,461.5 hours or 4.13×10^5 hours
How many days would this be?
$\frac{4.13 \times 10^5 \text{ hours}}{24}$ = 17,208 days or 1.7×10^4 days

How many years is this?
$\frac{1.7 \times 10^4 \text{ days}}{365}$

Approximately 47 years.
It would be possible for humans to survive the journey to Neptune but it is not likely they would live long enough to return to earth. (Consider that astronauts have to be a certain age before they even launch from earth. They would almost be senior citizens by the time they got to Neptune. Thanks to John Glenn, this is not out of the question.)

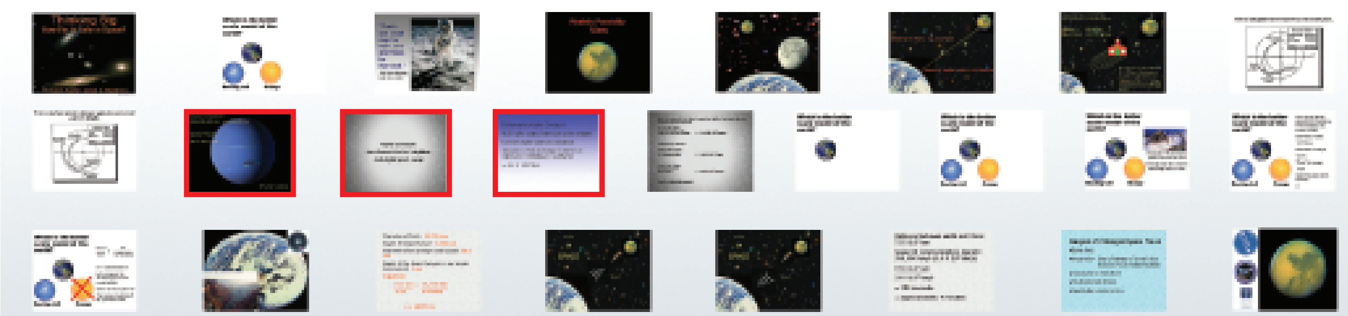


*For advanced students:
Slide 11: Alpha Centauri
Therefore, how would it be possible for humans to reach a far away place like Alpha Centauri, the nearest star to our solar system?



Slide 12: Alpha Centauri
Distance to Alpha Centauri:
4.35 light years from our solar system.
Convert light years to distance (one light year = 9.46×10^{12} km)

300,000 km/s X (60sec X 60min X 24hours X 365days X 4.35yrs)
= 4.1×10^{13} km



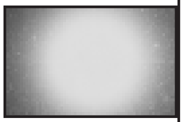
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



Slide 13: Alpha Centauri
How long would it take to get to Alpha Centauri at our current travel speed?

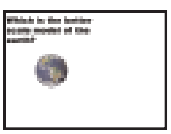
$$\frac{4.1 \text{ X } 10^{13}\text{ km}}{1.04 \text{ X } 10^{4}\text{ km/hour}} = 3.9 \text{ X } 10^{9}\text{ hours}$$

Convert to years:

$$\frac{3.9 \text{ X } 10^{9}\text{ hours}}{24\text{ hours/day}} = 1.6 \text{ X } 10^{8}\text{ days}$$

$$\frac{1.6 \text{ X } 10^{8}\text{ days}}{365\text{ days}} = 4.4 \text{ X } 10^{5}\text{ years}$$

That's 440,000 years!
Discussion: How would it be possible to travel so far? What would have to happen during travel in order for humans to reach the nearest star to our own solar system?
Answer: There would have to be many, many generations who live, procreate and die in space just to get to Alpha Centauri.
Discussion: How else could it be possible to travel such a distance?
Answer: Improved speed; better fuels; advanced propulsion system. Some physicists are currently working on a "sail" that would catch the solar winds and fly through space at superior speeds. Check out NASA's website to learn more about this research. (http://science.nasa.gov/headlines/y2000/ast28jun_1m.htm)



Slide 14: Ratio and Proportion
Even though these terms may be unfamiliar to some students, this type of reasoning is common. For example, if a runner travels one mile in ten minutes, how many miles would the runner traverse in twenty minutes? The answer is simple: 2 miles. The mathematical equation looks like this:

$$\frac{1\text{ mile}}{10\text{ min}} = \frac{X\text{ miles}}{20\text{ min}}$$

Solve for X: X= 2 miles
Let's use this technique for a more challenging problem:
Which is a better scale model for the earth: an orange or a bowling ball?
(Students will likely answer the orange after seeing and feeling its surface)
We will use references from the surfaces of each and compare them to the surface of the earth using mathematical excercises. In this way, we will find out which is a better model for the planet earth.

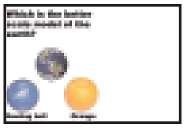
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

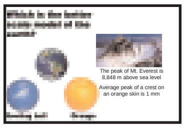
Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



Slide 15: The Grand Canyon and the Orange

Discuss: The orange seems to be an obvious answer because it has peaks and valleys, just like the Earth.



*Slide 16: The Orange

Q. Would the orange be the better scale model?

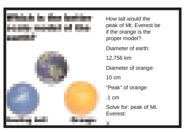
We can compare the highest "peak" on the skin of an orange to the highest peak on the face of the Earth.

Q. The tallest mountain on earth is located between Nepal and Tibet in central Asia. What is the name of this mountain?

A. Mt. Everest.

The peak of Mt. Everest is 8,848 meters above sea level.

If the orange is a good model for the earth, the biggest peak on the orange should correspond to the height of Everest. The biggest peak on an orange is 1 mm. We can use this information, plus the diameters of the Earth and the orange, to complete our proportion exercise.



Slide 17: The Bowling Ball and the Orange

Diameter of the Earth: 12, 756 km

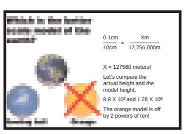
Diameter of an orange: 10 cm

Peak crest of orange: 0.1 cm (or 1 mm)

Questions for students:

Q. If the orange is a good model for the Earth, what will the equation yield as the height of Everest?

Keep in mind that this is a ratio and proportion exercise: units only need to be the same on respective sides of the = sign.



Slide 18: The Bowling Ball and the Orange

$$\frac{0.1\ \text{cm}}{10\ \text{cm}} = \frac{X\ \text{meters}}{12756000\ \text{meters}}$$

Solve for X

X = 127,560 meters. This is far too large a number!

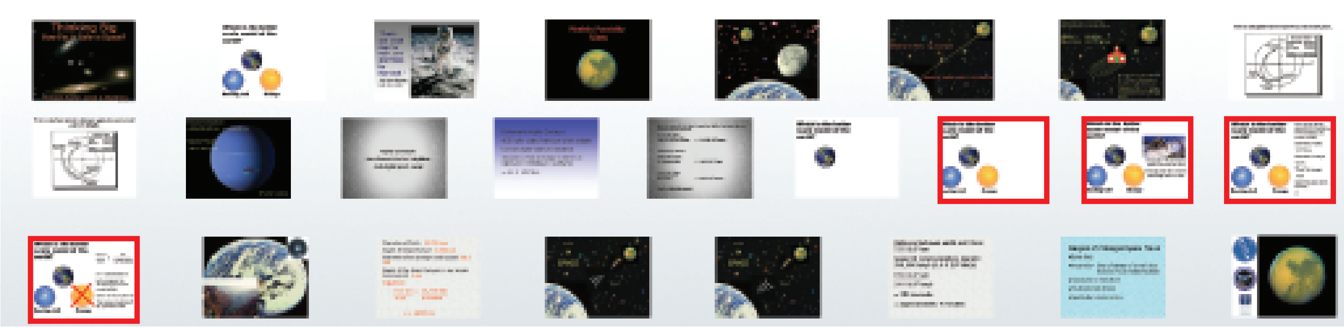
Let's compare the result for X with the real height of Everest in terms of magnitude.

$X = 1.28 \times 10^5$ meters

Real height of Everest = 8.8×10^3 meters

Subtract the exponents: 5-3 = 2

raise 10 to the result: $10^2 = 100$. The model peak is 100 times larger, in relative terms, than the real thing! The orange cannot be the model.



Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

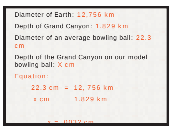
Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content

Slide 19: The Bowling Ball

To find out if the bowling ball is a good scale model, we can compare a measurement of the one of the deepest crevices in the earth to a scratch on the bowling ball.

We will use the Grand Canyon as our reference on earth. The Grand Canyon (located in Grand Canyon National Park, Arizona) at its widest point is 29 km across and 1.892 kilometers deep. It is this aspect, the depth, that we will concern ourselves with. (Another example of a deep crevice in the earth is the Challenger Deep near the Marianas Islands in the Pacific Ocean. This crevice has been measured at deeper than 35,000 feet below sea level.)



Slide 20: The Bowling Ball

Q. If we were going to represent the Earth with a bowling ball, how deep a scratch should we make for the Grand Canyon?

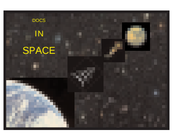
Diameter of Earth: 12,756 km
Depth of Grand Canyon: 1.829 km
Diameter of an average bowling ball: 22.3 cm
Depth of the Grand Canyon on our model bowling ball: X cm

$$\frac{22.3 \text{ cm}}{x \text{ cm}} = \frac{12,756 \text{ km}}{1.829 \text{ km}}$$

$$x = .0032 \text{ cm}$$

A. On our bowling ball, the depth of the Grand Canyon should be .0032 cm deep. This is a more realistic proportion. The bowling ball is the better model.

Viewed from the earth, Mars looks like it would have a very smooth surface. However, as we learned above, looks can be deceiving. Mars has mountains and trenches that are even larger than the ones on earth!



Slides 21-22: Communication Signals

Discussion: Medical emergencies are an urgent problem anywhere. Why is this of particular concern on Mars?

Answer: Because the astronauts are very far from doctors and hospitals.

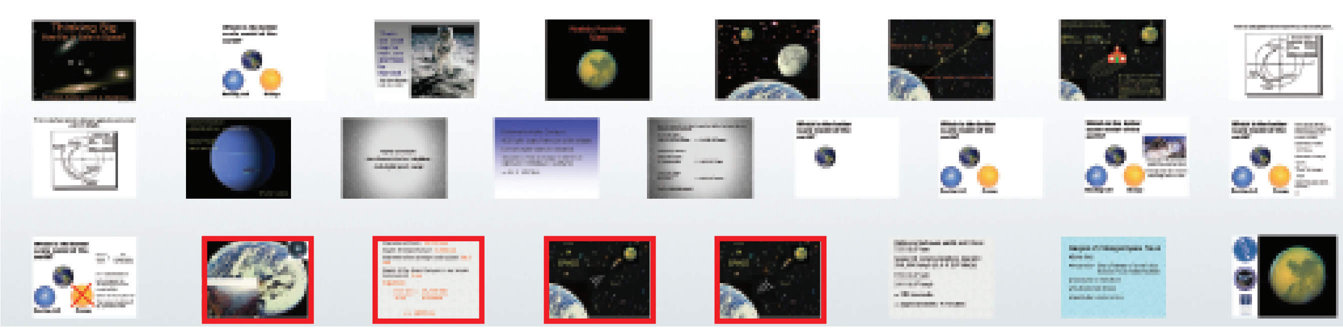
Discussion: What might NASA do the confront this problem?

Answer: Send a doctor with the crew.

Discussion: Which kind of doctor would be best to send?

Answer: One that has enough general knowledge to handle many different kinds of health emergencies. However, one doctor will not be enough to handle every possible scenario, so communication between experts on earth and the doctor and crew in space is going to be extremely important.

Time is of the essence. In a medical emergency like a heart attack or stroke, the victim has only moments to survive before the brain is deprived of too much oxygen. The time it takes for communications to be sent and received from a spacecraft on or near mars will be critical.



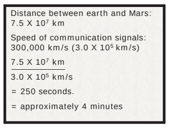
Thinking Big: How Far is Safe in Space?

National Content Standards:
A: Science as Inquiry
E: Science and Technology
F: Science in Personal and Social Perspectives
G: History and Nature of Science

Lesson Time: 45 minutes

Objectives: Students will learn:
to work with very large numbers;
to use powers of ten notation;
to use ratio and proportion;
challenges in space biomedicine

Lesson Content



Slide 23: Communication Signals

Q. How long will it take for these communications to be sent and received?

Distance between earth and Mars: 7.5×10^7 km

Discussion: How fast do radio waves travel?

Answer: Radio waves are part of the electromagnetic spectrum. They travel at the same speed as light.

Speed of communication signals: 300,000 km/s (3.0×10^5 km/s)

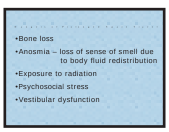
$$\frac{7.5 \times 10^7 \text{ km}}{3.0 \times 10^5 \text{ km/s}} = 250 \text{ seconds.} = \text{approximately 4 minutes.}$$

Q. This is the time for a one way communiqué. How long for the round trip?

A. Eight minutes.

Remember, experts on earth will have to formulate a response to a call for help and that will take time as well.

In the best scenario of an emergency, it will take at least eight minutes for the Mars mission crew to receive instructions.



Slide 24: Challenges in Prolonged Space Travel

The long space journey will raise many health issues for astronauts. Here are some that are being researched currently:

Bone loss;

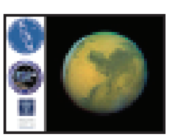
Anosmia - lack of sense of smell, in space due to congestion from redistribution of bodily fluids;

Exposure to radiation - unshielded without the earth's atmosphere;

Psychosocial stress;

Vestibular dysfunction.

Sending people to Mars appears to be an especially daunting task. In order for us to successfully send and retrieve people from Mars we need to train young scientists to be comfortable with these difficult, dangerous tasks. In order to reach the stars we must be thinking big!



"Every great advance in science has issued from a new audacity of imagination."
-John Dewey, The Quest for Certainty