Activity: Space Travel

BACKGROUND:

In the “From Earth to the Universe” exhibit, distances from Earth to astronomical objects are given in light-seconds, light-minutes or light-years. A light-second is the distance light travels in one second. The speed of light is about 300,000 kilometers per second so one light-second is a distance of approximately 300,000 kilometers. One minute is 60 seconds, so light can travel 60 times farther in a light-minute—about 1,800,000 kilometers (~ 2 million kilometers). One light-year is about 10 trillion kilometers.

Using these distance units, it would be very easy to figure out how long it would take to reach these astronomical objects if we had a rocket ship that could travel at the speed of light. It is impossible, however, for objects with mass to travel at this speed. According to Einstein’s theory of special relativity, if you could devise a way to travel very close to the speed of light, clocks in your spacecraft would run more slowly than ones on Earth. For example, if you traveled for a year at 99.98% of the speed of light, you would find upon your return that 50 years more had passed on Earth.

WHAT TO DO:

- ✓ Find each of the images on the following pages in the “From Earth to the Universe” exhibit, on the website at http://www.fromearthtotheuniverse.org/tour_images.php, or in the given flash cards.
- ✓ Record the distance to the object given in the caption for the image (on the website, click the image to go to the caption).
- ✓ Use these distances to complete the activities and answer questions as you travel into space. For some questions, you may wish to use the formulas below:

$$\text{AVERAGE SPEED} = \frac{\text{DISTANCE TRAVELED}}{\text{TIME OF TRAVEL}} \qquad \text{TIME OF TRAVEL} = \frac{\text{DISTANCE TRAVELED}}{\text{AVERAGE SPEED}}$$

$$\text{DISTANCE TRAVELED} = (\text{TIME OF TRAVEL}) \times (\text{AVERAGE SPEED})$$

DON'T FORGET:

- ✓ 1 light-second ≈ 300,000 km
- ✓ 1 light-minute ≈ 2 million km
- ✓ 1 light-year ≈ 10 trillion km
- ✓ speed of light ≈ 300,000 km/sec
- ✓ 50 X your travel time at 99.98% the speed of light ≈ time passed on Earth

PART A: THE MOON

DISTANCE FROM EARTH = ______________

1. On the next page is a one inch Earth and several Moons to the same scale. Cut out Earth and tape it to a blank wall or floor. Cut out a Moon for each person participating. Have each person tape their moon the distance they think it should be from Earth.

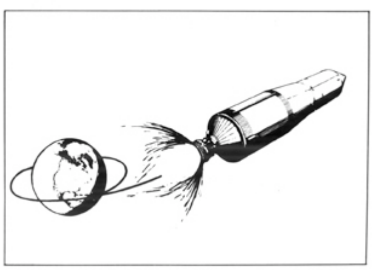
HINT: The distance from Earth to the moon is about 30 Earth diameters.

2. The Moon does not produce its own light. We see the Moon because of the light it reflects from the Sun. How many seconds does it take this light to travel from the Moon to Earth? ____________________ sec

3. How far away is the Moon in kilometers? ____________________km

HINT: Multiply the distance in light-seconds by 300,000 km/light-sec.

4. The Apollo 11 spacecraft, launched from Cape Kennedy on July 16, 1969, carried the first men to land on the Moon. Its average speed was about 5500 km/h. Estimate the time in hours for Apollo 11 to reach the Moon (use your previous answers and the equation for "time of travel"). ____________________ h



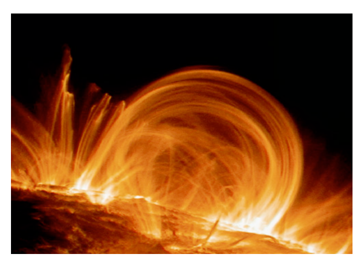
Translunar Injection

5. How does your estimate in #4 compare to the actual time from translunar injection (a propulsive maneuver used to set a spacecraft on a trajectory to the Moon) to lunar-orbit insertion as shown in the Apollo 11 time log below? What might account for any differences in these times?

EVENT	DATE & TIME (EST)	MISSION TIME
Launch	July 16 08:32:00 am	00:00:00
Translunar injection	11:16:16 am	02:44:16
CSM-LM docking	11:56:03 am	03:24:03
Lunar orbit insertion	July 19 12:21:50 pm	75:49:50

PART B: THE SUN

DISTANCE FROM EARTH = ______________

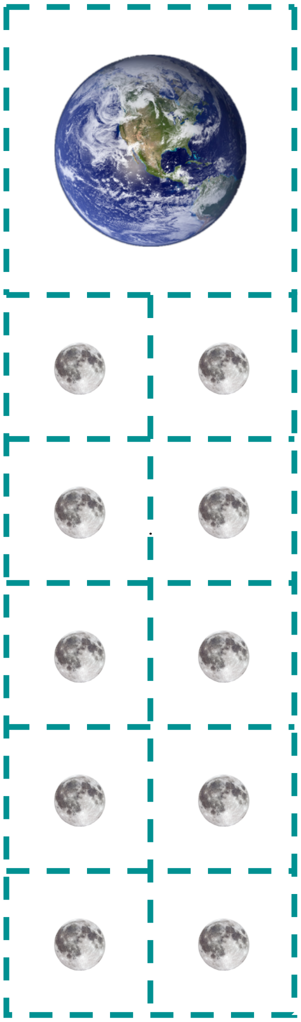


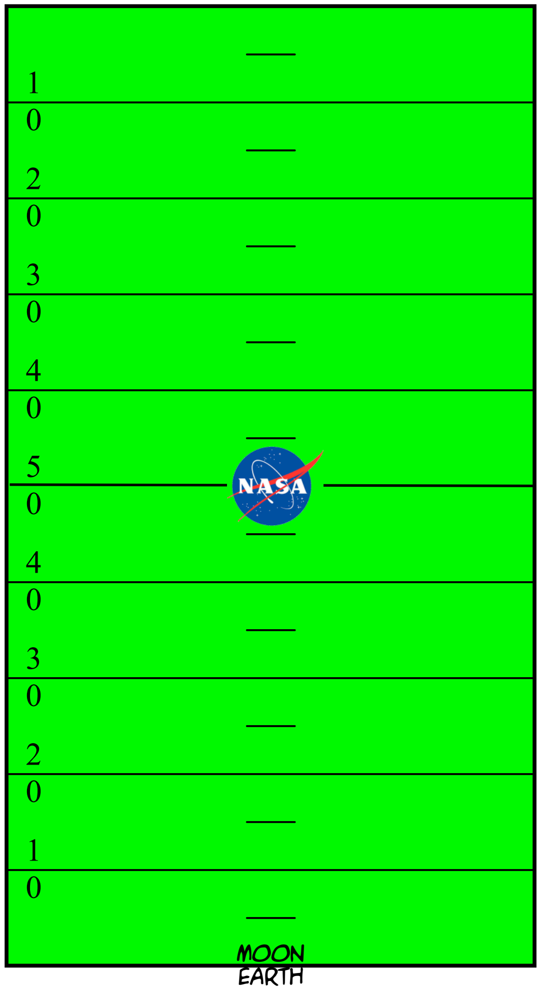
6. The length of one football field without the end zones is 100 yards or 300 feet. If a 1 inch Earth were at the 0 yard line, the moon would be just shy of the 1 yard line at 2.5 feet. Cut out the football fields on the next page and tape them end-to-end (the field with the words moon/earth should go first). Place the center of the Sun the correct distance from Earth.

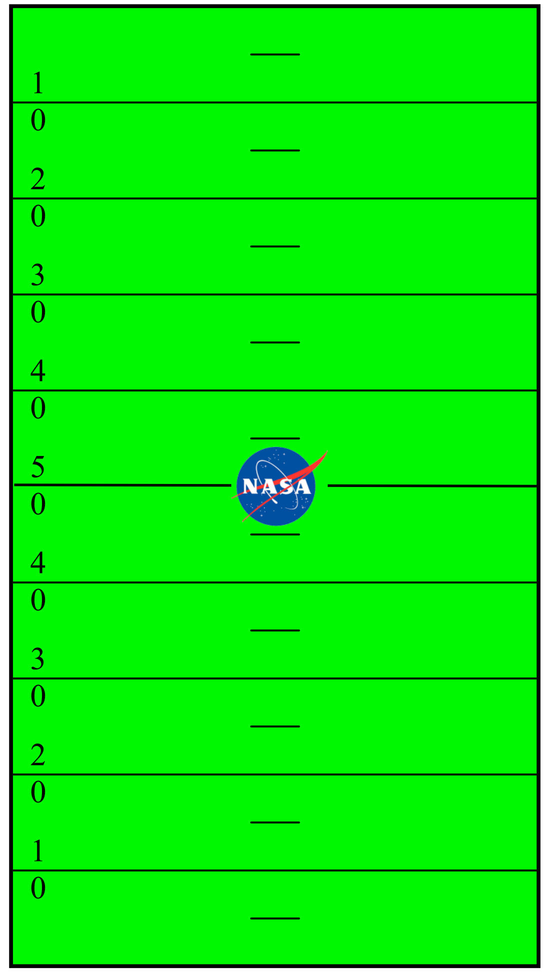
7. Scientists study astronomical objects by analyzing the light that comes from them. How many seconds would it take the light from these coronal loops on the Sun to reach the earth? __________________ sec

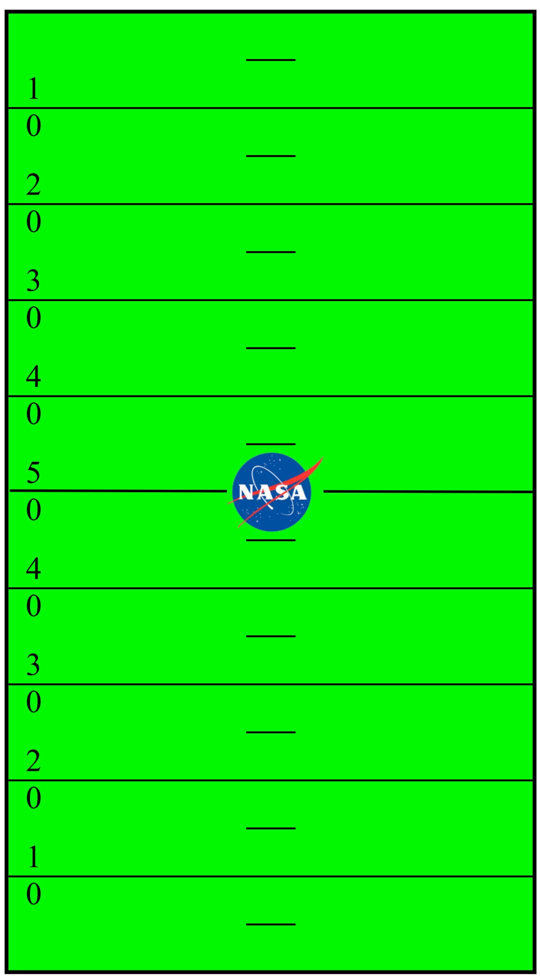
8. How many minutes old is the light that reaches us from the Sun? ______________________ min

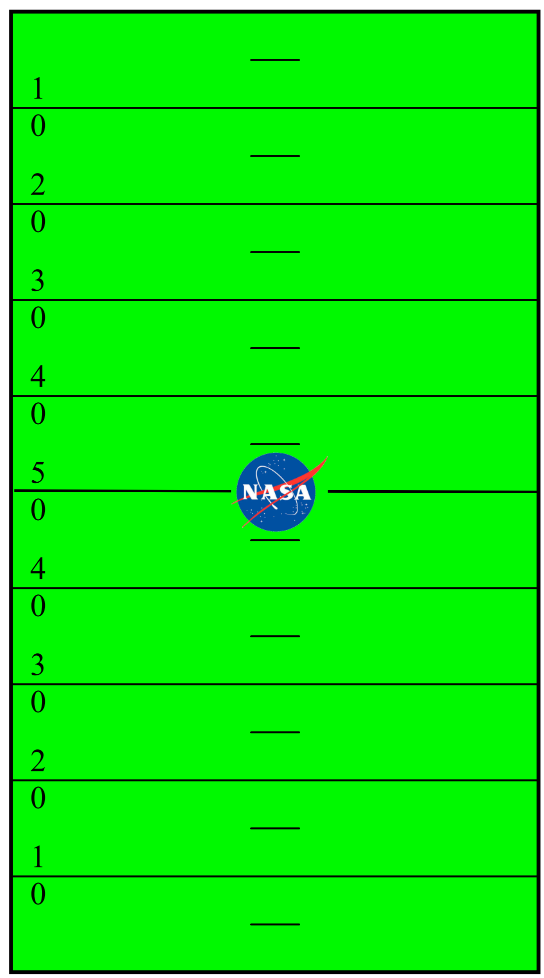
PART A









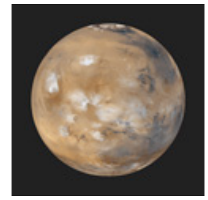


PART B →

NOTE: At this scale, Earth and the Moon would be only tiny dots!

PART C: MARS

DISTANCE FROM EARTH = ______________



9. Cut out the football fields below and tape them to the strip you made in part B on the other side of Earth from the Sun. Place Mars the correct distance from Earth. Note that the distance from Earth to Mars is given for *opposition*, the point at which it is closest to Earth.

10. Convert the distance given from Earth to Mars to kilometers. ______________ km

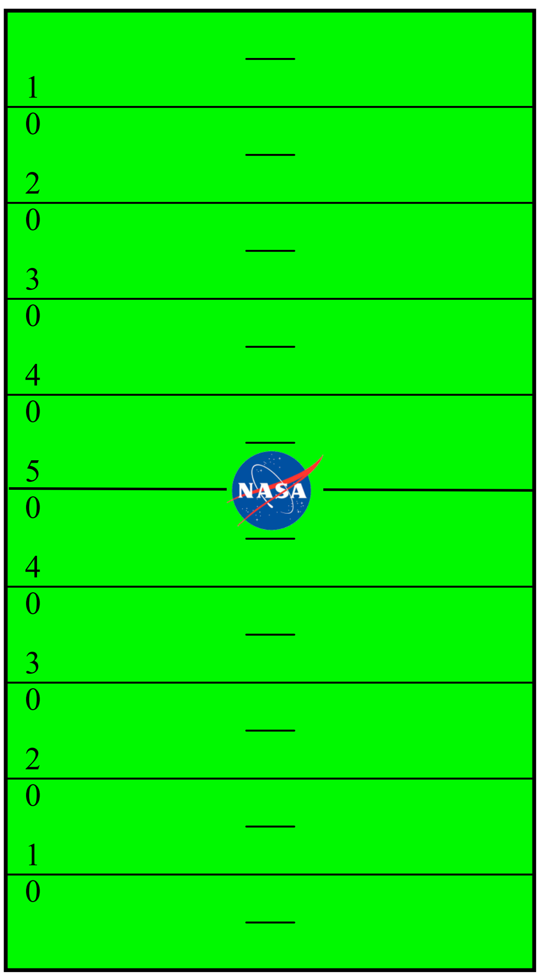
11. An episode of Scientific American Frontiers, "Journey to Mars" says that in one phase of a current mission plan to Mars, astronauts will travel for six months, across 250 million miles of space. 250 million miles is about 400 million kilometers. Compare this distance to the one in #10. Would the astronauts be traveling the shortest possible distance to Mars? Can you think of some reasons why or why not? (See the trajectory for the Phoenix Mars Mission on the next page.)

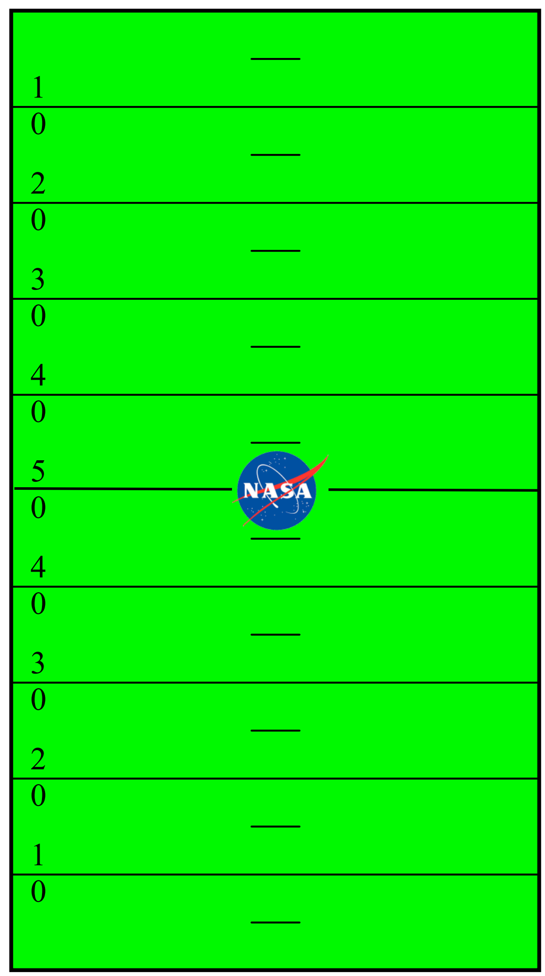
12. Six months is about 4000 hours. Using a distance of 400,000,000 km and a formula from the front page, estimate the average speed of the astronauts' spacecraft. How does this compare to the maximum speed of close to 40,000 km/h reached by Apollo 11? ____________ km/h

In comparison, Proxima Centauri, the closest star to our own, is 4.2 light years away. This is ~700,000 times further away from Earth than Mars (about twice around Earth's equator using your football field scale). At a speed of 100,000 km/h, it would take over 45,000 years to reach Proxima Centauri.

PART C →

MARS





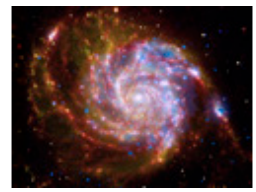
PART D: ANDROMEDA GALAXY   DISTANCE FROM EARTH = ______________

13. Andromeda is our closest galactic neighbor. We see Andromeda as it was how many millions of years ago? ____________________ million years ago

14. How far away is the Andromeda galaxy in kilometers? Watch out! You are dealing with huge numbers now! ____________________ million trillion km

15. At 100,000 km/h, you could travel about one trillion km per millennium (1000 years). How many millennia would it take to travel to Andromeda at this average speed? Do you think this could be possible for a manned mission? ________ millennia

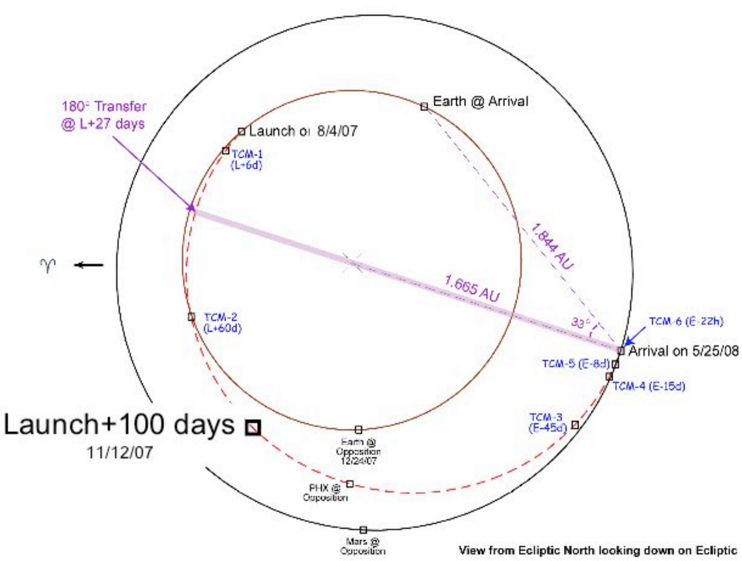
PART E: M101 (THE PINWHEEL GALAXY)   DISTANCE FROM EARTH = ______________



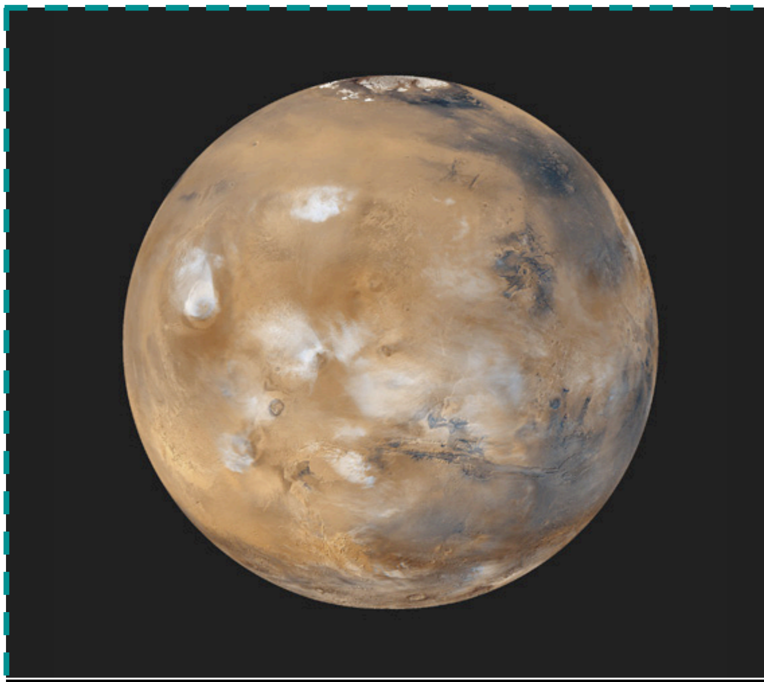
16. Now we are ready to send an unmanned spacecraft out into space at speeds close to that of light! How many light-years is a roundtrip to M101? _________ light-years

17. If our spacecraft could travel at at 99.98% of the speed of light, how long would such a journey take? ___________ years

18. Remember that on Earth, clocks would run 50 times more slowly than one on this spacecraft. In about 5 billion years, the sun will become a red giant with a radius larger than that of Earth's orbit. When our spacecraft returns from M101, will Earth still be there to receive it?



Trajectory correction maneuvers for the Phoenix Mars Mission launched on August, 4, 2007. Credit: Phoenix Mission, University of Arizona, 7/17/2007



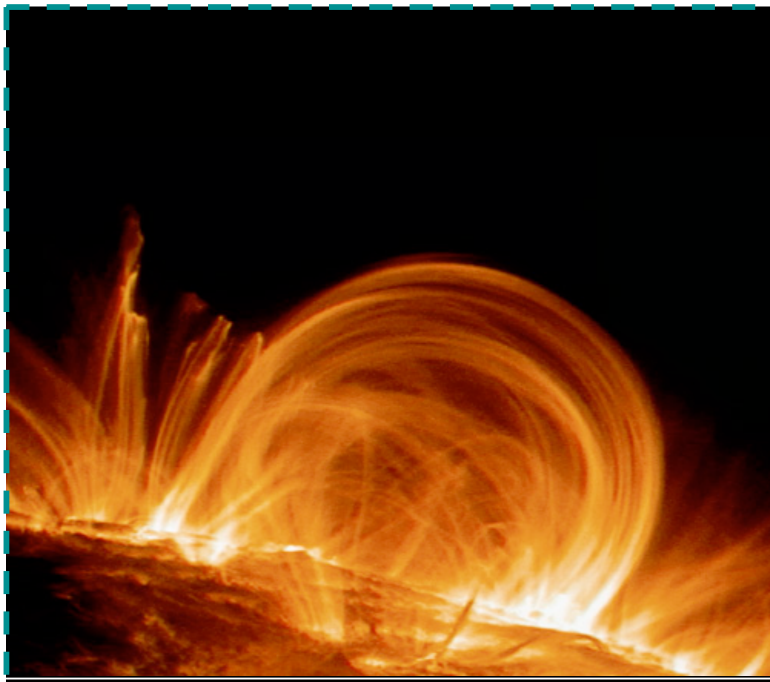
MARS (186 light-seconds)

This image of clouds over the surface of Mars comes from the Mars Global Surveyor, a spacecraft in orbit around the Red Planet. These high, wispy clouds are mainly comprised of water ice. To the lower left, they cover the peaks of the three large Tharsis Ridge volcanoes. At the far left, clouds are seen around the peak of Olympus Mons, the largest volcano in the Solar System. At top centre, the ice cap covering the Martian north pole is visible.

Credit: NASA / Mars Global Surveyor.

SPACE TRAVEL FLASH CARD →

MORE SPACE TRAVEL FLASH CARDS



CORONAL LOOPS OF THE SUN (499 light-seconds)

A close-up view of the edge of the Sun shows vast looping structures made of blisteringly hot, electrically charged gas (plasma) in the Sun's corona. Here the plasma is caught falling back to the Sun following an explosive solar flare in what is known as coronal rain.

Credit: Image made in ultraviolet light by the TRACE team of the Stanford-Lockheed Institute for Space Research and NASA.

M101 (23 million light-years)

This composite image shows galaxy Messier 101 (M101) , a swirling spiral of stars, gas, and dust whose diameter is nearly twice that of our Milky Way galaxy. Infrared data from Spitzer (red) reveals the galaxy's delicate dust lanes. In Hubble's visible light image (yellow), the bright clumps are regions where new stars have formed, while the core consists mainly of old stars. Meanwhile, X-rays from Chandra show the remains of exploded stars and million-degree gas that permeates the galaxy.

Credit: X-ray: NASA / CXC / JHU / K.Kuntz et al; Optical: NASA / STScI; Infrared: NASA / JPL-Caltech.

THE MOON (1.25 light-seconds)

A familiar sight to us all, the full Moon graces our night sky every 29 days. The lunar landscape is a mixture of bright highlands and dark â€œseasâ€ once filled with lava, both of which now show the scars of large impact craters and rays of ejected material. Scientists think the Moon itself was formed after a violent collision with the Earth billions of years ago.

Credit: Jean-Luc Dauvergne / Ciel et Espace

ANDROMEDA GALAXY (2.5 million light-years)

Andromeda is a spiral galaxy close to our Milky Way, and it is the largest galaxy visible to the unaided eye. By using ultraviolet light, astronomers can highlight different structures: blue colours represent light given off by brilliant young stars in the spiral arms, while orange tones are from the older, cooler stars in the galaxy's core. Billions of years from now, the Milky Way and Andromeda will merge.

Credit: Galaxy Evolution Explorer Team for NASA / JPL-CalTech.

Activity: Space Travel, answer key

PART A: THE MOON   DISTANCE FROM EARTH = 1.25 LIGHT-SECONDS

1. The Moon should be 30 inches or 2.5 feet from Earth.

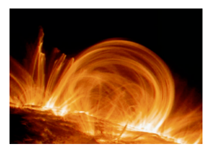
2. 1.25 sec

3. (300,000 km/light-sec) X (1.25 light-sec) = 375,000 km

4. (375,000 km) / (5500 km/sec) = 68 h

5. 75:49:50 – 02:44:16 = 73:05:34. Since Apollo 11 sped up and slowed down at various points on its journey to the Moon, we had to approximate with an average speed. Also note that a translunar injection is not a straight line path.

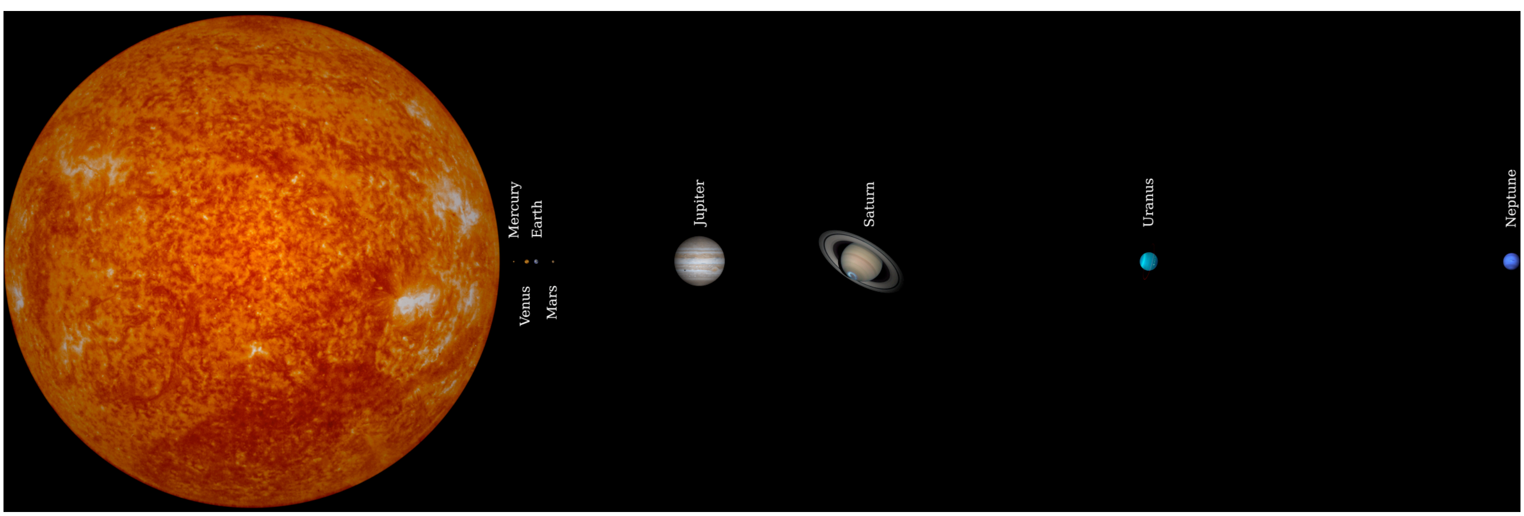
PART B: THE SUN   DISTANCE FROM EARTH = 499 LIGHT-SECONDS



6. (499 light-sec)/(1.25 light-sec) ≈ 400 times further than the Moon
(400) X (2.5 ft) / (3 ft/yd) = 333 yd (3 football fields + 33 more yards from Earth)

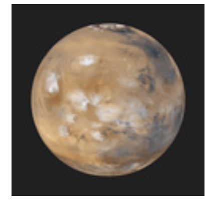
7. 499 sec

8. (499 sec) / (60 sec/min) ≈ 8 min (8.3 min)



Scale model of the solar system showing relative sizes of Sun and planets and relative orbital distances from the Sun. Please note that the sizes of the bodies are greatly exaggerated relative to the orbital distances.

PART C: MARS — DISTANCE FROM EARTH = 186 LIGHT-SECONDS



9. Mars: (186 light-sec)/(1.25 light-sec) ≈ 150 times further from Earth than the Moon (150) X (2.5 ft) / (3 ft/yd) = 125 yd (1 football field + 25 more yards from Earth on the other side from that of the Sun)

10. (300,000 km/light-sec) X (186 light-sec) ≈ 6 million km (5,580,000 km)

11. No, this is over 60 times as far. Trajectories of spacecraft need to take into account many things including the orbits of Earth and Mars around the Sun.

12. (400,000,000 km) / (4000 h) = 100,000 km/h, over twice as fast at the top speed reached by Apollo 11

PART D: ANDROMEDA — DISTANCE FROM EARTH = 2.5 MILLION LIGHT-YEARS

13. 2.5 million years ago

14. (2.5 million light-years) X (10 trillion km/light-year) = 25 million trillion km

15. (25 million trillion km) / (1 trillion km/millennium) = 25 million millennia, not very possible unless suspended animation becomes a reality!

PART E: M101 — DISTANCE FROM EARTH = 23 MILLION LIGHT-YEARS

16. (23 million light-years) X 2 = 46 million light-years

17. (0.9998) X (46 million years) ≈ 46 million years (45.99 million years)

18. (46 million years) X 50 = 2300 million years = 2.3 billion years; yes but it is still a long time to wait!

FOR MORE INFORMATION ON NASA MISSIONS, RELATIVITY, AND THE FUTURE OF INTER-STELLAR SPACE TRAVEL VISIT:

NASA Missions
http://www.nasa.gov/missions/index.html

World Book at NASA: Relativity
http://www.nasa.gov/worldbook/relativity_worldbook.html

Warp Drive, When?
http://www.nasa.gov/centers/glenn/technology/warp/warp.html