



EXPLORE!



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Office of Space Science and public libraries**

Activity: **Solar System: The Scale of the Solar System**

Level: **Grades 5-8**

To Take Home: **Drawing of the Solar System**

Background Information

The Solar System

The solar system began when gravity caused a cloud of dust and gas (mostly hydrogen) to condense about 5 billion years ago. The cloud was spinning, and this prevented all the material from falling in toward the center. It formed a rotating disk that flattened into a plane (called the “ecliptic”). Ninety-nine percent of the mass of the solar system was hydrogen and helium, while the remaining 1% was dust. The disk had a central bulge of material that condensed rapidly and heated up to a point where fusion began to occur. Thus was formed the central star of the solar system, our Sun.

Dust and gas particles continued to swirl around the Sun, which was now blowing out its solar wind in all directions. These dust particles began to join together and coalesce into larger fragments after about 10 million years. This process, known as accretion, formed the planets. Inner planets condensed with less gas because the solar wind combined with the heat of the Sun and became the inner “terrestrial” or rocky planets: Mercury, Venus, Earth, and Mars. The cooler outer regions of the solar system allowed the evolution of the gaseous planets: Jupiter, Saturn, Uranus, and Neptune. At a sufficient distance from the Sun, it is cold enough for ice to form in the disk, and the presence of ice allows more solid material to be available for planet building. The giant planets began with large cores of rock and ice and then swept up large amounts of gas to form thick atmospheres. Pluto, a tiny icy planet, is most likely a large member of the family of objects left over from the origin of the solar system that lie beyond the orbit of Neptune and contain comets.

Evidence of impacts occurring over millions of years can be seen in the cratered surfaces of the rocky planets and moons. Although much of this material has thinned out, there is still a great quantity of small debris that orbits the Sun and rains down on the planets in the form of meteors. Much of this material is the debris left by comets as they orbit the Sun, melt, and disintegrate. The seasonal meteor showers on Earth are actually composed of comet debris that the Earth passes through in its orbit around the Sun.

The Inner Planets

Mercury is a small rocky planet with no atmosphere. It is similar in size and appearance to our Moon. It is extremely hot and has a rotation (day) that is nearly as long as its orbital period (year) because of the Sun's strong gravitational pull. Venus has a thick atmosphere composed of carbon dioxide and sulfuric acid, which causes a severe greenhouse effect. It has many active volcanos and a surface temperature of over 900° Fahrenheit. Earth, located at a good distance from the Sun and fairly large, was able to maintain its rich atmosphere and oceans of water and developed life over millions of years. The many impact craters that were formed on Earth (as well as the other planets) are mostly invisible now because of erosion by water, weather, volcanism, and tectonics.

Mars has a very thin atmosphere consisting primarily of carbon dioxide and has very cold temperatures, as low as -125° Celsius (-190° Fahrenheit). Mars used to have a thicker, warmer atmosphere and probably running water, as evidenced by many former river beds, but the atmosphere is now much thinner, and its temperature is too low to support liquid water. Two ice caps at each pole contain frozen carbon dioxide and some water. Recently there has been new evidence (from possible fossils contained in meteorites thought to have come from Mars) that primitive bacterial life may have once existed on this planet.

The Outer Planets

The outer planets Jupiter, Saturn, Uranus, and Neptune are all gas giants with cores composed of ice and rock that formed in the cooler outer regions of the solar system. Jupiter, Saturn, Uranus, and Neptune have large amounts of hydrogen, the major element of the solar system. Uranus is tipped on its side with respect to its ecliptic path about the Sun, possibly due to an impact early in its formation. All the outer gaseous planets have ring systems or parts of ring systems. These have evolved in the past 100 to 200 million years from material created from moons and moonlets (tiny moons) impacting each other.

Pluto is made of mostly rock and ice and is generally thought to be the largest member of the outer region of objects that lie beyond Neptune and include comets called Kuiper Belt objects. All the major planets travel along the plane of the ecliptic except for the inclined plane of Pluto's orbit. Pluto crosses inside Neptune's orbit for a short period during each orbit around the Sun.

Moons

The moons of Mars are very small and are most likely captured asteroids from the asteroid belt (material that never coalesced into a planet because of the immense gravity of Jupiter). Earth's Moon was most likely formed when a large chunk of planetary material (about the size of Mars) impacted into Earth during its formative years. This hurled a large amount of material into orbit around Earth, which eventually coalesced into the Moon. The moons of the outer planets probably formed at the same time as the planets themselves out of material trapped by the gravitational pull of that planet. The moon systems of the large planets are quite like smaller versions of the solar system.

The moons of the giant planets are made up of rock and ice, some with small iron cores. Saturn's moon Titan has a thick atmosphere composed of nitrogen and methane and may be covered with an ocean of ethane or methane. Jupiter's moon Europa may harbor a liquid water ocean under its cracked icy surface. Another of Jupiter's moons, Io, has volcanos that are more active than any volcano on Earth. The largest moons of Jupiter and Saturn are larger than the planets Mercury and Pluto. Pluto's moon, Charon, is about half the size of Pluto.

Comets

Outside Neptune lies a region filled with debris left over from the formation of the solar system. This very cold region is composed mainly of comets made up of rock and ice. As the solar system orbits the center of our Milky Way galaxy, it passes nearby stars, which cause gravitational disturbances and knock comets in toward the Sun or out of the solar system. Comets that travel in toward the Sun always have their tails pointing away from the Sun due to the solar wind. Sometimes comets are maneuvered by the gravitational pull of planets into different orbits around the Sun or around a planet. This happened in 1994 when Comet Shoemaker-Levy was captured by Jupiter's gravity, broke apart, and eventually impacted the surface of the planet.

Asteroids

The asteroid belt, or region between Mars and Jupiter, is composed of thousands of catalogued asteroids (there are probably thousands more). Mostly rock, this material was never able to coalesce into a planet because of the massive gravity of Jupiter. Most asteroids are quite small; the largest known asteroid, Ceres, has a diameter of only 623 miles.

The Size of the Solar System

The scale of the sizes of the planets is one that is fairly easy to impart to students. A circle that is 36 feet in diameter can represent the Sun, and the paper cutouts (sizes given below) can be used to identify the planets. But at that scale, you cannot show the distances between the planets. The solar system is mostly just space! The distances are so large that you must use very small balls and grains of sand to represent the distances at a scale where you need to walk only four or five blocks to Pluto. By the time you reach the outer planets and look back at the Sun, it is merely a tiny speck in the sky.

You can also show a short video (or part of a video) to the group about the solar system (see book and video lists). **Timeframe - 15-30 minutes.**

The Solar System

Introduce or review the major components of the solar system: planets, moons, asteroids, and comets. As a group, brainstorm the answers to some general questions about the solar system.

What do all of the planets revolve around? Why?

All of the planets revolve around the Sun because it is so large and has gravitational influence over them.

Which planets are hot? Which are cold? Why?

The inner planets are warmer and the outer planets are colder because of their distance from the Sun.

What lies between the planets?

Between the planets lie mostly space, some comet debris, the asteroids, the solar wind, cosmic radiation, and a few human spacecraft.

What revolves around some planets? Why?

Moons and rings orbit many of the planets. The local gravitational pull of the planet outweighs the gravitational pull of the Sun (although each planet/moon/ring system orbits the Sun).

Why do planets have rings?

Material resulting from moons impacted by other moons and moonlets (tiny moons) has evolved into ring systems over the past one to two hundred millions years. Saturn's rings are the oldest; the rings of Jupiter, Uranus and Neptune are still evolving.

How did the solar system form?

The solar nebula formed from a cloud of gas and dust. Gravity pulled the gases in towards the center and formed the star. The material around the new star formed into planetesimals and finally into planets and moons.

Why would your weight be different on different planets?

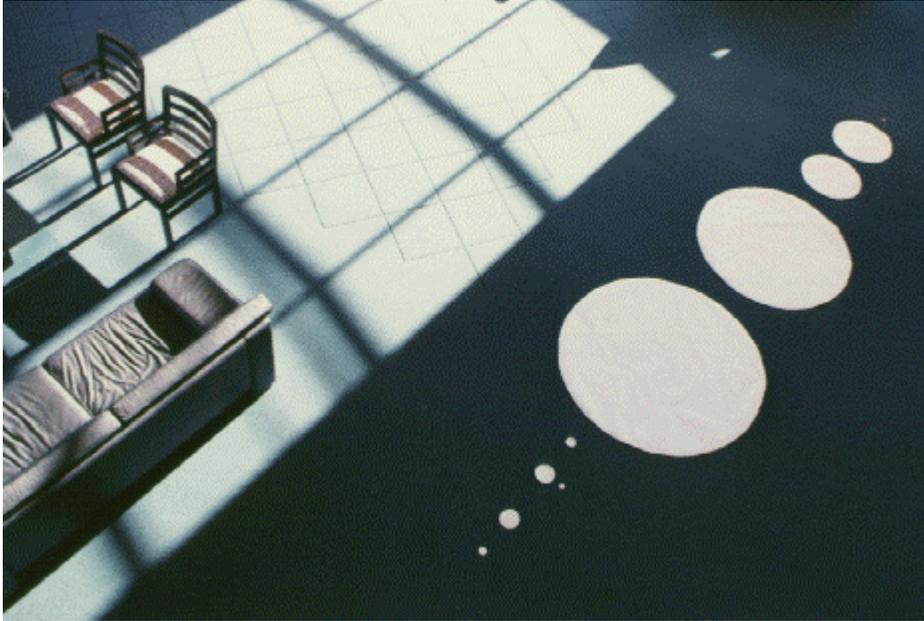
Your weight is different on different planets because the gravitational pull is different due to planet size.

Have the students draw the solar system as they know it. They can use the handouts to help guide them in the sizes of the planets. Have them use color. One easy way to remember the order of the planets is the phrase ***My Very Educated Mother Just Served Us Nine Pizzas***. The Asteroid Belt lies between Mars and Jupiter. Comets live outside the solar system in two regions called the Kuiper Belt and the Oort Cloud. Due to perturbations in the solar system, occasionally comets fall into orbits around the sun.

Timeframe - 15-30 minutes.

The Size of the Planets

Show them the cutout planets. Have them identify each planet one at a time and put them in order. If you can, bring the students to a location where you can point out an approximate "size" of the Sun (36-foot diameter circle). **Timeframe - 15 minutes.**



Procedure

1. Show the students the cutout planets in no particular order. Then ask, "Which planet might be Mercury?" "Jupiter?" (etc.) As they identify each of the planets, have them line them up in order (like in the photo above).
2. Ask them, "How big would Saturn's rings be at this scale?" At this scale Saturn's rings would be about half the diameter of the planet on each side.
3. Ask them, "How far away from one another would the planets have to be at this scale?" They would be very far apart, farther than we could show at this scale! Mercury *at this scale* would be 1,500 feet away from the Sun!

Scale of the Solar System

This activity allows the group to walk through the entire solar system to get an idea of the immense distances between the planets. Bring the students outside to the start of their journey through the solar system. Show them that you have scaled down all of the sizes from the preceding activity by a factor of 100. Now the size of the Sun is only about 4 inches across. This will allow you to walk to all of the planets *at this scale*. If you are limited by distance, you can walk the students to only Uranus and point out markers for Neptune and Pluto. Carry the table of distances and another star (5-inch globe or baseball) with you.

Have one student assigned to hold each planet's marker. Another student can mark the distance in yards (long strides) to that planet. Others can share some facts about that planet. **Timeframe - 30+ minutes.**

Procedures

1. Start by placing the Sun. Then walk the class to each of the planets and mark each with the flag or marker as you get there.
2. Note the size of the ball or grain of sand representing that planet. Some of the information in the table, such as the time it takes light or radio waves to travel from the Sun to each planet, helps to emphasize the large distances.
3. One way to envision the large distances between planets is by noting the time it takes spacecraft to travel from Earth to each planet. The precise time varies, depending on the orbit of each spacecraft, but the values in the table show the travel times for some NASA planetary probes.
4. From each planet, look back at the "Sun" and imagine how large it appears in the sky. Also point out that as one travels to the outer solar system, the great distance from the Sun means that it is quite cold. Temperatures range from a scalding 380°C (715°F) on Mercury, to -70°C (-94°F) on Mars, -143°C (-225°F) at Jupiter, and a frigid -235°C (-390°F) at Neptune and Pluto.



Note: In marking the distances make sure you remember to start counting with the number where you left off at (i.e. count to 5 yards, then start at 5 till you reach 9 yards, etc.)

Follow-Up Questions

The nearest star to the solar system is Alpha Centauri. When you get to Pluto, ask your students "How far away do you think it would be to Alpha Centauri, the nearest star *at this scale*?" Most are likely to say no more than a few miles.

Actually, at this scale, Alpha Centauri would be about 11 centimeters across and 3200 kilometers (2000 miles) away, roughly the distance from New Orleans to San Francisco. The brightest star in our sky is Sirius. At this scale it would be about 23 centimeters across and 6500 kilometers away (4000 miles), roughly the distance from New Orleans to Hawaii. For such small objects to be visible at such large distances, stars (including our Sun) clearly must radiate a great deal of energy.

If there is time, students can calculate their weight on different planets using the handout giving the surface gravity on each planet.

Recommended Videos

NASA (CORE)

Catalog: <http://core.nasa.gov> **To order by e-mail:** nasaco@leeca.esu.k12.oh.us

Solar System Exploration Videotape Collection

\$24.00, Grades 8-12, 75 minutes, 1992

Ten segments highlighting the Voyager, Magellan, Galileo and Ulysses missions to the planets.

The New Solar System

\$25.00, 60 Minutes, 1994, Finley-Holiday Films (800) 345-6707

<http://finley-holiday.com> <http://core.nasa.gov>

Enhanced visuals of planetary features from Mercury to Neptune.

On Robot Wings - A Flight Through the Solar System

\$25.00, 30 minutes, 1992, Finley-Holiday Film Corp., (800) 345-6707

<http://finley-holiday.com> <http://core.nasa.gov>

Other Video Resources

The Great Solar System Rescue

Small groups of students make up teams of experts (astronomers, meteorologists, geologists and space historians) searching for lost probes in our solar system. Armed with a packet of material, students must work together analyzing visual data from the video to form theories about each probe's location. Also includes a refresher in planetary basics to theory-building exercises to a selection of cross-cultural views of the heavens.

Our Solar System - The Inner Planets. 1992

Earth's neighbors are revealed with animations and NASA photos as the "Assistant Professor" takes the viewer on a guided tour of Mercury, Venus, Earth, the Moon, and Mars.

Our Solar System - The Outer Planets. 1992

Close-up photographic and animated views of the giant outer planets of our solar system illustrate their surprising composition and vital statistics.

What's Out There? Exploring the Solar System

Explore the solar system starting with various early ideas about the universe to the dawning of the space age. This video supports the fact that our knowledge and understanding of the mysterious solar system is constantly being broadened and updated. Grades 4-6

Books you can borrow from your library

Non-fiction

Simon, Seymour. *Our Solar System.* William Morrow & Company. 1992. ISBN: 0688099920.

Dickinson, Terence. *Other Worlds: A Beginner's Guide to Planets and Moons.* Firefly Books. 1995. ISBN: 1895565715.

Riley, Peter D. *Our Solar System.* Readers Digest. 1998. ISBN: 1575842440.

Kerrod, Robin. *The Children's Space Atlas: A Voyage of Discovery for Young Astronauts.* Millbrook Press. 1992. ISBN: 156294164X.

Vogt, Gregory L. *The Solar System: Facts and Exploration* (Scientific American Sourcebooks). Twenty-First Century Books. 1995. ISBN: 0805032495.

Ride, Sally; O'Shaughnessy, Tam. *Voyager: An Adventure to the Edge of the Solar System* (Face to Face With Science). Crown Publishers. 1992. ISBN: 0517581574.

Verba, Joan Marie. *Voyager: Exploring the Outer Planets.* Lerner Publications Company. 1992. ISBN: 0822515970.

Kelch, Joseph W. *Small Worlds: Exploring the 60 Moons of Our Solar System.* Julian Messner. 1990. ISBN: 0671700138.

Fiction

Hirst, Robin; Hirst, Sally. *My Place in Space.* Orchard Books. 1992. ISBN: 0531070301.

Cole, Joanna; Degen, Bruce. *The Magic School Bus Lost in the Solar System.* Scholastic Trade. 1992. ISBN: 0590414291.

Magazine

StarDate Guide to the Solar System

University of Texas at Austin, McDonald Observatory

2609 University Avenue #3.118, Austin, TX 78712

Phone: (512) 471-5285 <http://stardate.utexas.edu>

Related Internet Sites:

The Nine Planets

<http://seds.lpl.arizona.edu/nineplanets.nineplanets/>

Students for the education and development of space

Views of the Solar System

<http://bang.lanl.gov/solarsys/eng/homepage.htm>

Our Solar System

<http://athena.wednet.edu/curric/space/planets/>

Origin of the Solar System (story and images)

<http://www.psi.edu/projects/planets/planets.html>

Origin of the Moon (story and images)

<http://www.psi.edu/projects/moon/moon.html>

HANDOUT - PLANET FACTS AT A GLANCE

| PLANET | MERCURY | VENUS | EARTH | MARS | JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|------------|-------------------------|-----------------|-----------------|-----------------|-----------------|-------------------------|-------------------------|-----------------------|
| Distance from Sun (millions of miles) | 36 | 67.2 | 93 | 141.6 | 483.6 | 888.2 | 1786 | 2799 | 3,666 |
| Period of Revolution (year)* | 87.97 days | 224.7 days | 365.26 days | 686.9d ays | 11.86 years | 29.46 years | 84.07 years | 164.82 years | 248.6 years |
| Period of Rotation (day)* | 58.65 days | 243.01 days retro-grade | 23 hrs. 56 min. | 24 hrs. 37 min. | 9 hrs. 56 min. | 10 hrs. 40 min | 17 hrs. 14 min. | 16 hrs. 6 min. | 6.39 days retro-grade |
| Inclination of Axis (degrees) | 0 | 177.3 | 23.5 | 25.2 | 3.08 | 26.7 | 97.9 | 29.6 | 122 |
| Inclination of Orbit to Ecliptic (degrees) | 7.0 | 3.39 | 0 | 1.85 | 1.31 | 2.49 | .77 | 1.77 | 17.15 |
| Diameter (miles) | 3,031 | 7,521 | 7,926 | 4,219 | 88,729 | 74,975 | 31,763 | 30,775 | 1,429 |
| Atmosphere | None | Carbon dioxide | Nitrogen Oxygen | Carbon dioxide | Hydrogen Helium | Hydrogen Helium | Hydrogen Helium Methane | Hydrogen Helium Methane | Methane |
| Moons | 0 | 0 | 1 | 2 | 16 | 18 | 17 | 8 | 1 |
| Rings | 0 | 0 | 0 | 0 | 3 | 1,000+ | 11 | 5 | 0 |

*Periods are given in Earth time

YOUR WEIGHT ON OTHER WORLDS

Multiply Your Weight by the Surface Gravity to get the result for the Last Column. For example, on Venus if you weighed 100 lbs, $100 \times .91 = 91$ lbs

| Planet | Surface Gravity | My Weight |
|---------|-----------------|-----------|
| Mercury | .18 | |
| Venus | .91 | |
| Earth | 1 | |
| Moon | .6 | |
| Mars | .38 | |
| Jupiter | 2.54 | |
| Saturn | 1.07 | |
| Uranus | .87 | |
| Neptune | 1.14 | |
| Pluto | .07 | |

HANDOUT - Planetary Scale

If the Sun is the size of a baseball approximately 54" in diameter, the sizes and distances of the planets are given in the chart below. Using this scale, you can mark the distances with flags beginning in your school gymnasium or athletic field and walking the distances to each planet. One very large stride can be measured as one yard. As you can see by this demonstration, most of space is just that, SPACE.

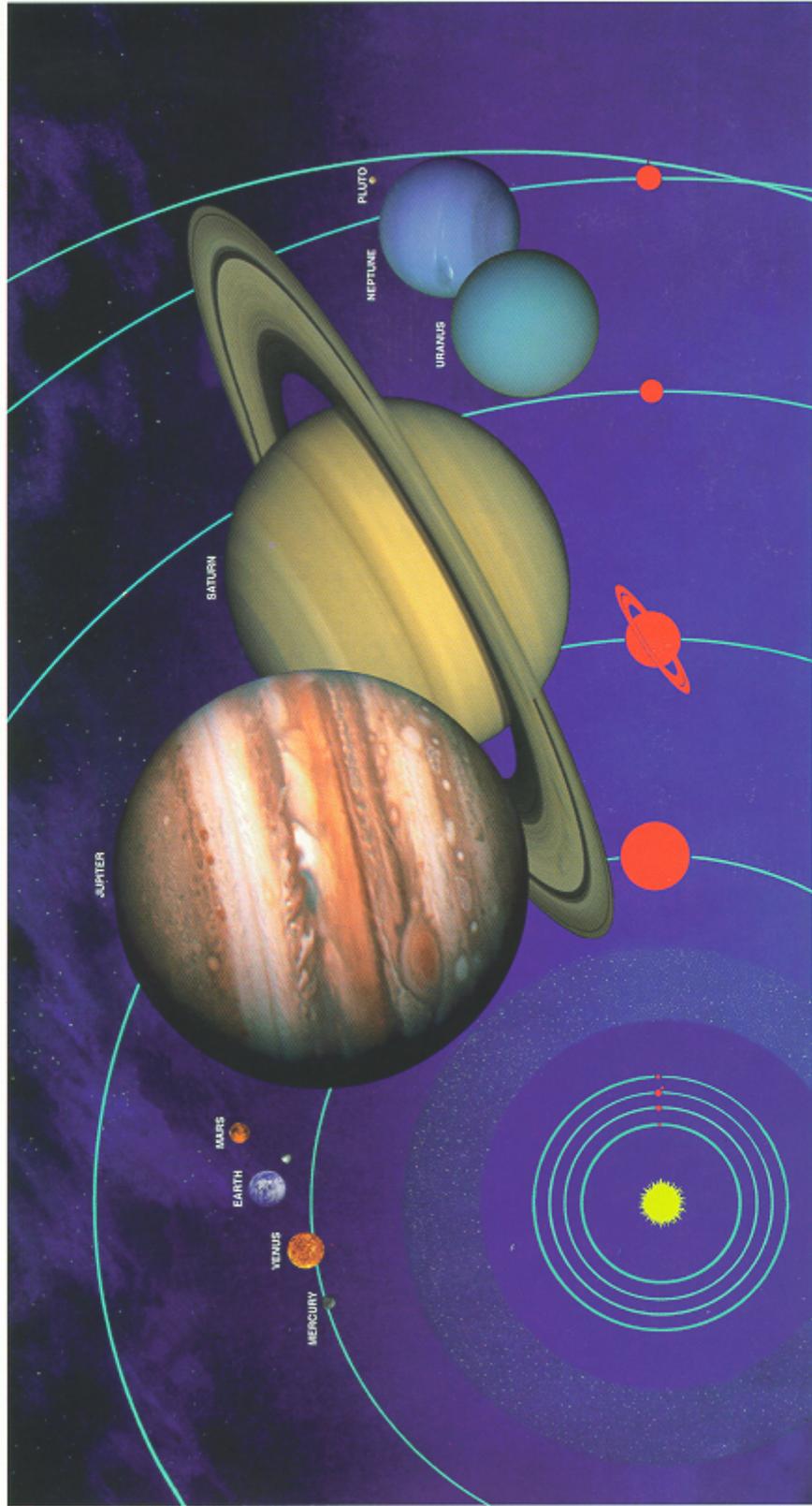
At this scale, what city or place could you estimate for the nearest star?

| SCALE SIZE of PLANET | REPRESENTATIVE OBJECT | DISTANCE | Light Time From Sun | Spacecraft Trip |
|-------------------------------|------------------------------|-------------------------|-------------------------------|------------------------|
| SUN | ORANGE | @ CENTER | | |
| MERCURY | GRAIN OF SAND | @ 15' (5 yd) | 3.2 minutes | 5 months |
| VENUS | GRAIN OF SAND | @ 28' (9 yd) | 6 minutes | 3 months |
| EARTH | GRAIN OF SAND | @ 38' (13 yd) | 8.3 minutes | |
| MOON | GRAIN OF SAND | 1" from Earth | 1.3 seconds from Earth | 3 days |
| MARS | GRAIN OF SAND | @ 59 (20 yd) | 12.7 minutes | 8 months |
| ASTEROIDS | DUST | @ 99' (33 yd) | 21 minutes | 1 year |
| JUPITER | 3/8" BALL | @ 200' (66 yd) | 43 minutes | 1.5 years |
| SATURN | 2/8" BALL | @ 367' (122 yd) | 1.3 hours | 3.2 years |
| SATURN'S RINGS | 2/3" Diameter Disk | Around Planet | | |
| URANUS | 1/8" BALL | @ 741' (247 yd) | 2.7 hours | 8.5 years |
| NEPTUNE | 1/8" BALL | @ 1161' (348 yd) | 4.2 hours | 12 years |
| PLUTO | GRAIN OF SAND | @ 1520' (507 yd) | 5.5 hours | not yet visited |
| NEAREST STAR = 10 1/2" | BASKETBALL | @ ?? | | |



National Aeronautics and
Space Administration

Our Solar System





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Our Solar System

Activities

How big is our solar system? To give you a rough idea, consider that it took the *Voyager 2* spacecraft, traveling in a sweeping arc at an average 65,000 kilometers (40,000 miles) per hour, 12 years to reach Neptune! How fast is that in meters per second? In feet per second? If you could travel that fast, how long would it take you to reach the next town? To get to the Moon?

Can you build a scale model of the solar system? If you use Earth's diameter as a unit of measure (Earth diameter = 1), figure out how big the other planets are compared to Earth. Hint: divide each planet's diameter by Earth's diameter. What objects might you use to depict the sizes of the Sun and planets? How far away would the planets be from each other? Map out a scale model of the solar system in your town.

| | Actual Diameter (km) | Mean Distance from Sun (km) | No. of Moons |
|---------|----------------------|-----------------------------|--------------|
| Sun | 1,391,900 | 0 | - |
| Mercury | 4,878 | 57,910,000 | 0 |
| Venus | 12,104 | 108,200,000 | 0 |
| Earth | 12,756 | 149,600,000 | 1 |
| Moon | 3,476 | - | - |
| Mars | 6,794 | 227,940,000 | 2 |
| Jupiter | 142,984 | 778,330,000 | 16 |
| Saturn | 120,536 | 1,429,400,000 | 18 |
| Uranus | 51,118 | 2,870,990,000 | 15 |
| Neptune | 49,528 | 4,504,300,000 | 8 |
| Pluto | 2,300 | 5,913,520,000 | 1 |

References

- Views of the Solar System—Solar System
<http://bang.lanl.gov/solarsys/>
- Planetary Photo Journal: <http://photojournal.jpl.nasa.gov/>
- Stardate, The University of Texas at Austin, McDonald Observatory, 2609 University Ave., #3.118, Austin, TX 78712

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There are 61 natural satellites (also called moons) around the various planets in our solar system, ranging from bodies larger than our own Moon to small pieces of debris. Many of these were discovered by planetary spacecraft. Some of these have atmospheres (Saturn's Titan); some even have magnetic fields (Jupiter's Ganymede). Jupiter's moon Io is the most volcanically active body in the solar system. An ocean may lie beneath the frozen crust of Jupiter's moon Europa, while images of Jupiter's moon Ganymede show historical motion of icy crustal plates. Some planetary moons, such as Phoebe at Saturn may be asteroids that were captured by planet's gravity.

From 1610 to 1977, Saturn was thought to be the only planet with rings. We now know that Jupiter, Uranus, and Neptune also have ring systems, although Saturn's is by far the largest. Particles in these ring systems range in size from dust to boulders to house sized, and may be rocky and/or icy.

Most of the planets also have magnetic fields which extend into space and form a "magnetosphere" around each planet. These magnetospheres rotate with the planet, sweeping charged particles with them. The Sun has a magnetic field, the heliosphere, which envelops our entire solar system.

Ancient astronomers believed that the Earth was the center of the Universe, and that the Sun and all the other stars revolved around the Earth. Copernicus proved that Earth and the other planets in our solar system orbit our Sun. Little by little, we are charting the Universe, and an obvious question arises: are there other planets around other stars? Are there other planets where life might exist? Only recently have astronomers had the tools to indirectly detect large planets around other stars in nearby galaxies. Direct detection and characterization of such planets awaits development of yet more powerful observing tools and techniques.

From our small world we have gazed upon the cosmic ocean for thousands of years. Ancient astronomers observed points of light that appeared to move among the stars. They called these objects planets, meaning wanderers, and named them after Roman deities—Jupiter, king of the gods; Mars, the god of war; Mercury, messenger of the gods; Venus, the goddess of love and beauty, and Saturn, father of Jupiter and god of agriculture. The stargazers also observed comets with sparkling tails, and meteors or shooting stars apparently falling from the sky.

Since the invention of the telescope, three more planets have been discovered in our solar system: Uranus (1781), Neptune (1846), and Pluto (1930). In addition, there are thousands of small bodies such as asteroids and comets. Most of the asteroids orbit in a region between the orbits of Earth and Mars, while the home of comets lies far beyond the orbit of Pluto, in the Oort Cloud.

The four planets closest to the Sun—Mercury, Venus, Earth, and Mars—are called the *terrestrial planets* because they have solid rocky surfaces. The four large planets beyond the orbit of Mars—Jupiter, Saturn, Uranus, and Neptune—are called *gas giants*. Tiny, distant, Pluto has a solid but icier surface than the terrestrial planets.

Nearly every planet—and some of the moons—has an atmosphere. Earth's atmosphere is primarily nitrogen and oxygen. Venus has a thick atmosphere of carbon dioxide, with traces of poisonous gases such as sulfur dioxide. Mars' carbon dioxide atmosphere is extremely thin. Jupiter, Saturn, Uranus, and Neptune are primarily hydrogen and helium. When Pluto is near the Sun, it has a thin atmosphere, but when Pluto travels to the outer regions of its orbit, the atmosphere freezes and "collapses" to the planet's surface. In this regard, Pluto acts like a comet.