## OUR SOLARSYSTEM: SUN, MOON, \& MORE

## Learning Outcomes

- Define astronomical unit (AU).
- Distinguish between solar flares, solar prominences, and sunspots.
- Describe the Moon in terms of temperature, atmosphere, gravity, and terrain.
- Identify the phases of the Moon.
- Explain what causes a solar and lunar eclipse.
- Define comet.
- Explain the differences between an asteroid, meteoroid, meteor, and meteorite.


## Important Terms

asteroid - a small rocky body orbiting the Sun; usually found in the asteroid belt astronomical unit (AU) - unit of measurement used to measure distances in our solar system comet - a small, icy body orbiting the Sun meteor - a small streak of light; when a meteoroid enters the Earth's atmosphere it becomes a meteor meteorite - a meteor that enters Earth's atmosphere and actually hits Earth's surface
meteoroid - clump of dust or rock orbiting the Sun
micrometeorite - very small dust-sized bits of matter
photosphere - thin shell of the Sun's outer layer
solar flares - short-lived high energy discharges from the Sun
solar prominences - larger energy discharges from the Sun that can be thousands of miles high and
last for months
solar system - the Sun and the bodies that orbit around it
sunspots - darker, cooler areas of the Sun

When you hear "solar system" what do you think of? Most of us probably think of the planets within our solar system. Some of us might think about the Sun. These are good responses because they are part of our solar system. What is our solar system? Our solar system is the Sun, the planets and their satellites, asteroids, comets, and any celestial body that comes under the gravitational influence of our Sun. This gravitational influence means that these bodies orbit the Sun. The word solar means anything pertaining to or proceeding from the Sun. So, the Sun is the key feature of our solar system. Our solar system, however, is just one of many in the universe. In 2010, astronomers reported that approximately $15 \%$ of the stars in the Milky


Way Galaxy may be part of systems like our solar system - and that is just within our galaxy. "With billions of stars out there, even narrowing the odds to $15 \%$ leaves a few hundred million systems that might be like ours," said astronomer Andrew Gould.

## THE SUN

The Sun is the most important element of our solar system. Without its heat and light, the Earth would be a lifeless, ice covered planet. On Earth, the Sun sustains our lives, and it gives energy which provides food and oxygen. It stirs our atmosphere and initiates our weather.

The Sun is a star. All other bodies of the solar system revolve around it. Because of this, the Sun is the point of reference for most facts about our solar system. When people talk about distances in our solar system, they tell how far something is from the Sun. For instance, the Earth is 93 million miles from the Sun. Because distances of most planets from the Sun are millions of miles away, scientists use a unit of measurement called the astronomical unit (AU) to measure distances within our solar system. Because we are most familiar with the distance from Earth to the Sun, the distance of 93 million miles ( $149,668,992 \mathrm{~km}$ ) is the start for measuring in astronomical units. The distance of 93 mil lion miles equals 1 AU . The measurement of 2 AU equals 186 million miles, and so on. So, you may say either, "The Earth is an average of 93 million miles from the Sun," or, "The average distance between the Sun and the Earth is 1 AU." Venus, as another example, is about 0.7 AU from the Sun. How far away is Neptune? It is about 30 AU from the Sun. Try calculating how many miles that is if 1 AU equals 93 million miles. You are correct if your answer is about 3 billion miles ( 2.793 to be exact).

When talking about the size of planets, one often compares them to the size of the Sun. The Sun is 300,000 times as massive as the Earth. If the Sun were hollow, you could fit approximately 1 million Earths inside it. Our solar system, our world, could not exist without the Sun.

The Sun is a medium-sized star composed of about $90 \%$ hydrogen, $9 \%$ helium, and minor amounts of several other elements. Its diameter is 864,000 miles $(1,390,473 \mathrm{~km})$. You could fit 100 Earths across the diameter of our Sun. The temperature of the Sun ranges from $7592^{\circ} \mathrm{F}\left(4,200^{\circ} \mathrm{C}\right.$ or 4473 K$)$ in its coolest regions to over $27,000,032^{\circ} \mathrm{F}$ ( 15 million degrees C or $15,000,273 \mathrm{~K}$ ) at its center.

As just mentioned, the Sun consists mostly of hydrogen and helium. The hydrogen is converted into helium by nuclear fusion. This process generates and releases the Sun's energy in all directions, all of the time. It is generally accepted that the Sun is a giant thermonuclear reactor, releasing a tremendous amount of energy.

The core of the Sun is so hot that no solid or liquid molecules can exist. Virtually, all atoms remain in a plasma state. The energy released within the core has to make its way to the surface, atom by atom. It's theorized if the Sun's fusion reaction were to suddenly halt, it would take more than 100,000 years before any effect would show on the surface of the Sun.

The very thin shell of the Sun's outer layer is called the photosphere. This is the part of the Sun that gives off light. It is also the visible surface that we see. This shell is composed mostly of hydrogen and helium, and is very hot. Its temperature is more than $10,000^{\circ} \mathrm{F}$.

The outer layers of the Sun indicate constant motion and violent activity. Solar disturbances occur all of the time. Sometimes they last for less than a second, and other times they last for years. These solar disturbances are usually associated with sunspots. Sunspots are darker, cooler areas of the Sun. From these sunspots, solar flares and solar prominences occur.

Solar flares are short-lived, high-energy discharges, that are potentially dangerous. They can harm satellites, ground systems, space-



The Sun showing solar prominences
craft, and astronauts. We monitor the Sun's activity closely so we can react quickly when flares occur. The less dangerous electromagnetic radiation from a flare will reach Earth in less than 9 minutes. The more dangerous high-energy particles may take 15 minutes to 3 days to get here. Space operators must be prepared to act quickly. As explained in NASA's Radbelts website, "During the Apollo program, there were several near-misses between the astronauts walking on the surface of the Moon and a deadly solar storm event. The Apollo 12 astronauts walked on the Moon only a few short weeks after a major solar proton flare would have bathed the astronauts in a 100 rem blast of radiation. Another major flare that occurred halfway between the Apollo 16 and Apollo 17 moonwalks would have had a much more deadly outcome had it arrived while astronauts were outside their spacecraft playing golf. Within a few minutes, the astronauts would have been killed on the spot with an incredible 7000 rem blast of radiation."

Solar prominences are larger and longer lasting high-energy discharges. Prominences can reach thousands of miles and last for months.

On rare occasions here on Earth, we may experience an event known as a solar eclipse. This occurs during the daylight hours when the Moon moves directly between the Sun and the Earth, blocking the Sun for a short time as it continues its orbit around the Earth. This is rare, however, because the Moon's orbital path around the Earth is tilted at about $5^{\circ}$ compared to the orbital path of the Earth around the Sun. You will learn more about this when you read about lunar eclipses. (See associated Activity Nine at the end of the chapter.)

## THE MOON

The Earth has one Moon and it is situated in an elliptical (oval-shaped) orbit around the Earth. Because it is elliptical and not circular, the Moon's distance from the Earth changes slightly. The distance varies from approximately 252,000 miles $(405,555 \mathrm{~km})$ at its farthest point to 221,000 miles $(355,665 \mathrm{~km})$ at its nearest point, with the average distance being close to 240,000 miles ( $386,243 \mathrm{~km}$ ). You could fit about 30 Earths between the Earth and the Moon. While the Earth's diameter is about 7,920 miles


The Earth's Moon $(12,746 \mathrm{~km})$, Earth's Moon has a diameter of about 2, 155 miles ( 3,468 km ), which is close to $1 / 4$ of the Earth's diameter. If you could travel to the Moon in a car at a speed of 65 miles per hour, you could reach the Moon in about 154 days. The Apollo astronauts who traveled to the Moon had to reach a speed of about 25,000 miles per hour to escape Earth's gravitational pull. They made it to the Moon in about 3 days traveling at an average speed of about 3,418 miles $(5,500 \mathrm{~km})$ per hour. (See associated Activity Ten at the end of the chapter.)

The Moon's gravitational pull is weak compared to that of Earth's; therefore, the weight of objects on the Moon would be different compared to Earth. The gravitational pull of the Moon is $1 / 6$ that of Earth's. This means, if someone weighs 90 pounds on Earth, the person would only weigh 15 pounds on the Moon. Divide your weight by 6 to determine how much you would weigh on the Moon.

Due to this weaker gravitational pull, the Moon has no atmosphere. The gravity of the Moon is too weak to trap any gases, such as oxygen, carbon dioxide, nitrogen, and so on. Because of this,

there is no wind or air of any kind on the Moon. Sound travels through air; therefore, there are no sounds on the Moon. The astronauts who went to the Moon during NASA's Apollo Program were able to communicate due to the air in their spacesuits and their lunar lander.

While there are no oceans, lakes, streams, or polar ice caps on the Moon, scientists had reason to believe that water ice might exist on the Moon due to evidence from past unmanned lunar missions. Scientists were excited to find conclusive evidence of water on the Moon thanks to data obtained from NASA's LCROSS (Lunar Crater Observation and Sensing Satellite) mission. In 2009, the LCROSS probe collected and transmitted information about a plume of lunar dust and particles created by the impact of a two-ton rocket slamming into a lunar crater. The crater, which is visible from Earth and is named Cabeus, is permanently shadowed on the Moon's south pole. This is important because the temperature of sunlit areas on the Moon can reach $250^{\circ} \mathrm{F}\left(121^{\circ} \mathrm{C}\right)$, which means water would quickly evaporate, and the gases would easily escape into space due to the Moon's weak gravitational pull. For water to exist, it would need to be in the form of water ice, which would only be possible in a dark or shaded area on the Moon, such as the crater Cabeus. The initial data from the LCROSS mission revealed approximately 24 gallons of water. As for LCROSS, it also slammed into the crater, as planned, approximately 4 minutes after the rocket. Its hugely successful mission brings to light many more questions such as, "How did the water ice get there?" "How much water ice is on the Moon?" and "How could we use this resource to benefit human exploration of the Moon?"

The Moon consists mainly of solid rock covered with dust. This fine dust covers the entire surface of the Moon. There are two theories on how the dust got there. Some think the impact of meteoroids striking the surface pulverized lunar matter into dust, which settled to the surface slowly and evenly. Others think the dust is cosmic dust from space that the Moon's gravitational pull brought to the surface.

Primarily, the Moon has two types of terrain, highlands and lowlands. The highlands are filled with craters surrounded by mountains, and the lowlands are filled with craters that have been flooded with molten lava and appear as dark areas called maria (Latin for sea).

The Moon has many different kinds of rocks. We learned this from the lunar landings. Moon basalt is a dark gray rock with tiny holes from which gas has escaped. It closely resembles Earth basalt, but contains different mineral combinations. On the Moon, basaltic lava makes up the dark, smooth surfaces of the lunar plains, which cover about half of the visible side of the Moon.

Probably the most common rock on the Moon is anorthosite. This rock is composed almost entirely of one mineral, feldspar. Anorthosite is


The surface of the Earth's Moon
found in the highlands of the Moon and shows up from Earth as the light areas of the Moon. Anorthosite is rare on Earth, but is found in Greenland and is believed to be an ancient rock.

The Moon rotates on its axis in the same amount of time it takes to orbit the Earth (27 days). Therefore, the same side of the Moon (near side) always faces the Earth. One-half of the surface of the Moon is illuminated by the Sun, and the other half is in shadow. However, the amount of surface we see, the phase of the Moon, depends on how much of the near side of the Moon is in the sunlight. As the Moon rotates around the Earth, its position relative to the Sun changes. As seen from the Earth, this means that
 a part of the surface of the Moon that is in shadow is facing the Earth. When the Moon is on the side of the Earth nearer the Sun, the Moon is new. When it is on the opposite side of the Earth the Moon is full. Study the pictures of the Moon phases below to help you understand the shapes of the Moon that are visible at different times during the month. (See associated Activity Eleven at the end of the chapter.)

Sometimes, the Moon passes directly in Earth's shadow. When this happens, part or all of the Moon may not be visible. This is called a lunar eclipse and occurs when the Sun, Earth, and Moon line up in just the right way. If the Moon passes through the penumbra, the light shadow cast by the Earth, the Moon is partially eclipsed. If the Moon passes through the umbra, the darkest part of the shadow cast by the Earth, the Moon is totally
 eclipsed. When the Earth's shadow prevents the entire surface facing the Earth to be blocked, it is called a total lunar eclipse. If the Moon rotates around the Earth each month, why doesn't a lunar eclipse occur each month? It is because the Moon is tilted about $5^{\circ}$ in its orbital path around Earth compared to the orbital path of the Earth around the Sun; therefore, the Moon usually passes a little above or below the Earth. As explained at Space.com, "To visualize, think of two Hula Hoops (one inside of the other) - one big and one small -floating on the surface of a pool. Push the inner one down so that half of it is below the surface and half above. When the Moon gets into the ecliptic - right at the surface of the pool - during its full phase, then a lunar eclipse occurs. "

A Moon day lasts 27 Earth days; the time it takes to orbit the Earth. Daytime on the Moon lasts about 13-14 Earth days, one half the orbit time; the other half being nighttime.

Temperatures on the Moon can rise above $250^{\circ} \mathrm{F}\left(121^{\circ} \mathrm{C}\right)$ during the day. Nighttime temperatures can go below $-250^{\circ} \mathrm{F}\left(-157^{\circ} \mathrm{C}\right)$.

Although the Earth and stars are beautiful when observing them from the Moon, the Moon is a quiet, barren place with a black sky. To date, only twelve astronauts have walked on the Moon's surface as part of six Apollo missions between 1969 and 1972. Apollo 11 astronaut Buzz Aldrin described the Moon as "magnificent desolation." With no atmosphere, no running water, and extreme
temperatures, the Moon is a gray, lifeless ball orbiting the Earth. Without spacesuits and life-supporting vehicles or habitats, humans could not survive on our Moon. (See associated Activity Twelve at the end of the chapter.)

## OTHER BODIES

Asteroids, comets, and meteoroids are part of our solar system and therefore orbit around the Sun. Collectively, they are thought of as debris orbiting in space. You


Asteroids might wonder why they are important to us. Well, one reason is safety. Space planners and space travelers need to consider these phenomena as they prepare to go deeper into space. Let's take a quick look at each of these individually and learn a little more about them.

Asteroids are chunks of rock that range in size from particles of dust to some that are a few hundred miles across. Most asteroids in our solar system travel in an orbit between Mars and Jupiter. This area is known as the asteroid belt.

The first asteroid was discovered by an Italian astronomer, Guiseppe Piazi, in 1801. Since that time, more than 15,000 asteroids have been found and catalogued. Scientists speculate that there are probably millions more of them in our solar system. Scientists know of more than 200 asteroids whose orbits come close to our Earth and are capable of hitting us. However, the closest any have come is about 100,000 miles ( $160,934 \mathrm{~km}$ ).

Spacecraft have flown through the asteroid belt and found that large distances separate asteroids. In October 1991, the asteroid known as Gaspra was visited by the Galileo spacecraft and became the first asteroid to have high-resolution images taken of it. Gaspra is composed of metal-rich silicates and looks like a lumpy potato-shaped rock.

In 1997, the spacecraft Near Earth Asteroid Rendezvous (NEAR) made a high-speed, close encounter with the asteroid Mathilde. Scientists found Mathilde to be a carbon-rich asteroid. NEAR went on to encounter the asteroid Eros in 1999-2000. Eros had numerous boulders protruding above the surrounding surface.


Comet

Earth-based observations of asteroids continue, too. In May 2000, scientists observed the boulder Kleopatra with the 1,000 foot telescope of the Arecibo Observatory. Kleopatra is a metallic, dog bone-shaped rock the size of the state of New Jersey.

A comet is described as a giant dirty snowball. It is irregularly shaped with a tiny nucleus composed of frozen gases, water, dust, and icy lumps. Comets are usually a few miles across. Comets generally travel around the outer regions of our solar system, but sometimes they are bumped off their orbit and head toward the Sun. As they approach the Sun, comets usually grow in size and brightness. As the comet moves closer to the Sun, the comet's ice parts begin melting into a gaseous and dusty tail that can extend for millions of miles.

Sometimes, comets remain in their new orbits and repeat their journey; therefore, scientists can sometimes predict future travel paths of comets. For instance, Halley's Comet reappears every 76 years.

English astronomer Sir Edmund Halley first suggested that comets were members of our solar system. After studying bright objects in the sky, he predicted the appearance of a comet in 1758.

When it appeared, the comet was named after him. Halley's comet continues to make regular appearances in our skies. It last approached the Sun in 1996.

Very small, dust-particle size bits of matter are called micrometeorites. From this size upward, these tiny particles of dust and sand orbiting the Sun are called meteoroids. Meteoroids are usually leftover from a comet. If a meteoroid enters the Earth's atmosphere it is called a me-
 teor. If the meteor is large enough to penetrate our atmosphere and actually hit the surface of the Earth it is called a meteorite.

Meteorites are not that common, but they have occurred. However, meteors are very common. Friction causes a meteor to heat and glow and begin to disintegrate leaving a trail of luminous matter. When there are many meteors seen in the sky within a period of an hour, it is called a meteor shower. Meteor showers are also referred to as shooting stars. They can be seen on just about any night if you get out in the country away from the city lights.

Meteorites are the pieces of matter that remain when debris does not burn up completely as it passes through the atmosphere and lands on the surface of the planet. Scientists believe many meteorites hit the Earth each year, but it is rare to actually see it happen. Most meteorites are basketballsize or smaller, but larger pieces can and do impact the surface of the Earth. Some meteorites are small pieces of an asteroid; others have proved to be material blasted off the surface of the Moon following an impact on its surface. Other meteorites have been determined to originate on Mars.

The recent recovery of a carbonaceous chondrite meteorite from the Yukon has excited scientists who say that its very primitive composition and pristine condition may tell us what the initial materials were like that went into making up the Earth, Moon, and Sun. Only about two percent of meterorites are carbonaceous chondrites containing many forms of carbon and organics, the basic building blocks of life. This type of meterorite is easily broken down during entry into the Earth's atmosphere, so recovery is quite rare. (See associated Activity Thriteen at the end of the chapter.)

## Summary

The Sun is a star and is the most important element of our solar system. The Sun releases a tremendous amount of energy in the form of heat and light, which is essential for life on Earth. The Moon, on the other hand, does not produce heat or light. Its environment is very different from Earth's, and without spacesuits and life-supporting vehicles or habitats, humans could not survive on our Moon.

Our solar system also includes comets, meteoroids, and asteroids. After reading detailed information about these objects, you should be able to explain how they are different from one another.

When thinking about our solar system, you probably immediately think of planets. In the last chapter, we will visit each of the planets in our solar system.

## ACTIVITY SECTION

## Activity Nine - Build a Solar Cooker

Purpose: This is the practical way to show how energy from the Sun can be used.
Materials: shoe box, aluminum foil, plastic wrap, a skewer, and some hot dogs

## Procedure:

1. Line the shoe box with the foil.
2. Insert a skewer through one of the short sides.
3. Insert the skewer through a hot dog (lengthwise) and then stick the skewer into the other short side of the box.
4. Cover with the plastic wrap.
5. Place the solar cooker in sunlight and let the Sun cook your lunch. You could try baking cookies from refrigerated cookie dough, as well.

Summary: The solar cooker uses sunlight as its energy source. The aluminum foil helps keep the light and heat from the Sun in the cooking area, increasing its intensity. The plastic wrap over the top allows the sunlight to enter the box, but helps prevent heat from escaping. The temperature inside the solar cooker then becomes hot enough to heat the hot dog. A discussion of how solar energy can be used in our country would be beneficial at this time.

## Activity Ten - Earth-Moon Distance

Purpose: This activity will give both a visual and mathematical comparison of the distance to the Moon from the Earth using scale models to represent the actual objects.

Materials: world globe (important that the globe is 12 inches in diameter), tennis ball, string (at least 30 feet long), reference book or internet site (as noted below), measuring tape, and calculator or pencil/paper for calculators

## Procedure:

1. With the tennis ball representing the Moon, ask students to place the tennis ball at a distance from the globe that represents how far the Moon is from the Earth. (Use the information found on page 28 that states that you could fit about 30 Earths between the Earth and the Moon.) This will be a visual representation of the distance from the Earth to the Moon.
2. Next, as a mathematical representation of the distance, and a way to actually measure the scaled distance, ask students to determine the circumference of the Earth by consulting a reference book or using the internet, or use the summary information on next page. Using this circumference, the students should use the information on page 28 that tells that the distance from the Earth to the Moon is about 240,000 miles and determine how many times the circumference of the Earth it would take to measure the distance from the Earth to the Moon. To do this, the students should divide the distance to the Moon by the Earth's circumference. (The summary will give the mathematical outcome.)
3. Compare the earlier visual idea of the distance between the Earth and the Moon with measured distance based on the Earth's circumference. To do this, wrap the string around the globe 9.5 times. Then hold one end of the string at the surface of the Earth and stretch the string across the classroom. The other end of the string represents the distance of the Earth to the Moon. Measure the distance.

Summary: The Earth's circumference is about 25,000 miles. The distance from the Earth to the Moon is about 240,000 miles. When you divide the distance between the Earth and the Moon by the circumference of the Earth you get 9.6 or, averaged 9.5 . Using this scale, the distance from the model Earth to the model Moon should be 9.5 times the circumference of the model Earth, or about 30 Earths away, as calculated in the equation below.
Mathematically:

$$
\mathrm{C}=\pi \mathrm{d}
$$

$$
\mathrm{C}=3.14 \times 12^{\prime \prime}
$$

$$
\mathrm{C}=37.68^{\prime \prime}
$$

Then, $37.68^{\prime \prime} \times 9.5=357.96^{\prime \prime}$ or
29.83 ft (about 30 ft , or 30 Earths)


## Activity Eleven - Seeing the Moon

Purpose: Demonstrate why we see different portions of the Moon (phases of the Moon) illuminated in the sky due to light and shadows.

Materials: a dark room, a bright light source (a table lamp), a small ball (tennis or baseball), and the demonstrator (a person doing the demonstration for the others)

## Procedure:

1. Hold the ball at arm's length toward the bright lamp.
2. Ensure the room is dark except for the table lamp. With the lamp representing the Sun, the head of the demonstrator becomes the Earth, and the ball is the Moon.
3. The demonstrator should stand in place; slowly turning to the left so that the ball in the outstretched hand moves in a complete circle. Observers will be able to see the changing phases of the Moon on the ball.

Summary: As shown in the illustration of the phases of the Moon on page 30, as the Moon makes its 27-day orbit of the Earth, the amount of sunlight that reaches the Moon when it is not in the Earth's shadow determines the surface of the Moon that can be seen from Earth. The phases of the Moon are said to determine many factors on Earth, such as are found in reference books, called Almanacs.

## Activity Twelve - Lost on the Moon - Survival

Purpose: This activity accomplishes several things: the analysis of the Moon's atmosphere, the evaluation of the importance of available materials while on the Moon, the identification of similarities and differences between the Earth and Moon, the use of critical thinking skills, and the promotion of team building.

Background: Your spaceship has just crash-landed on the dark side of the Moon. You were scheduled to rendezvous with your mother ship 200 miles away, on the lighted surface of the Moon, but the rough landing has destroyed your ship and ruined all but the 15 items listed below.

Since your crew's survival depends upon reaching the mother ship, you must choose the most critical items available for the 200-mile trek across the Moon's surface. You must determine the "priority" of survival items and list them. Back on Earth, NASA would have given you their priority, but no contact can be made. The decision is yours. How would your team skills compare to those of the NASA home team? It's fun to compare your answers with those of NASA and other teams.

Materials: checklist of items provided, a pencil or pen

|  | ITEMS | NASA <br> RANKING | YRUR <br> RANKING | ERROR <br> POINTS | GROUP <br> RANKING | ERROR <br> POINTS |
| ---: | :--- | :---: | :---: | :---: | :---: | :---: |
| 1 | Box of matches |  |  |  |  |  |
| 2 | Food concentrate |  |  |  |  |  |
| 3 | 50 of nylon rope |  |  |  |  |  |
| 4 | Parachute silk |  |  |  |  |  |
| 5 | Solar powered heating unit |  |  |  |  |  |
| 6 | Two 45 caliber pistois |  |  |  |  |  |
| 7 | One case of Pet milk |  |  |  |  |  |
| 8 | Stellar map |  |  |  |  |  |
| 9 | Two 100-pound oxygen tanks |  |  |  |  |  |
| 10 | Self-inflating life rafts |  |  |  |  |  |
| 11 | Magnetic compass |  |  |  |  |  |
| 12 | Five gallons of water |  |  |  |  |  |
| 13 | Signal Flares |  |  |  |  |  |
| 14 | First aid kit containing injection needles |  |  |  |  |  |
| 15 | Solar powered FM transceiver |  |  |  |  |  |
|  | TOTALS |  |  |  |  |  |

## Procedure:

1. Divide the group into small teams.
2. Hand out a copy of the problem or read it to the teams.
3. Have students rank the 15 items in their order of priority.
4. After the students are done, have them discuss and justify their rankings to the other teams.
5. Show the students the NASA rankings.
6. Calculate the error points for individuals and teams, using the NASA ranking on the next page.

Calculate error points for the absolute difference between the NASA ranking and the individual
or group ranking. Scoring: $\quad 0-26=$ Excellent
$27-32=$ Good
33-45 $=$ Fair
46-112 $=$ Still lost on the Moon
Summary: An understanding of the lunar environment and an ability to critically think and discuss ideas are necessary to make good judgments regarding the importance of the items on the survival list. Working as a team to make these selections is beneficial in making good decisions.

## Lost on the Moon

## RANKINGS



Calculate error points for the absolute difference between the NASA ranking and the individual or group ranking. Scoring: 0-26 Excellent

56-112 Still lost on the Moon

## Activity Thirteen - Meteoroids and Space Debris

Purpose: Demonstrate the penetrating power of a projectile with a small mass and how it differs depending on the velocity (speed and direction).

Materials: two or three raw potatoes (depending on group size), several large diameter plastic straws (Each person should get a chance to participate.)

## Procedure:

1. Hold the raw potato in one hand.
2. While grasping the straw with the other hand, stab the potato with a quick sharp motion. The straw should completely penetrate the potato. CAUTION - Don't strike your other hand.
3. Again, hold the potato and now stab it with the straw using a slow push. The straw should bend instead of penetrating the potato.

Summary: Even a small mass can penetrate many things if its velocity is high enough. This was demonstrated by the straw penetrating the potato. Meteoroids and space debris traveling at high speeds pose significant hazards, particularly to space walking astronauts. Spacesuit material is made of special layers of materials to help protect astronauts from meteoroids and small space debris.

## OUR SOLAK SYSTEM: THE HLANETS

## Learning Outcomes

- Define planet.
- State basic facts about the planets in our solar system.
- Define and identify dwarf planets.

Officially, our solar system contains eight planets. Most of us can probably name them, and are somewhat familiar with them. You may be thinking, "Wait. I thought there were nine planets." That was true until 2006 when the International Astronomical Union (IAU), the governing body of astronomy, revised the definition of "planet," which left Pluto out of the traditional planet category.

The IAU's definition of planet is "a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit." Let's take a few moments and look at some interesting facts about each planet, as well as Pluto. We'll start with Mercury and go in order of each planet's distance from the Sun.

## Mercury

Mercury is the closest planet to the Sun, yet it is the most difficult to see because of the Sun's glare on it. (Don't look for Mercury while the Sun is in the sky. It could damage your eyes.) Mercury is slightly larger than the Earth's moon and is the smallest of the eight planets.

Mercury is only 36 million miles ( 0.39 AU ) from the Sun and revolves around the Sun every 88 days. It has a very elliptical orbit, and it moves about 30 miles ( 48 km ) every second. Mercury rotates very slowly, taking 59 Earth days to rotate on its axis.

Mercury, which has no


The surface of Mercury as seen from Mariner 10


Mercury moons, has a rocky, crusty surface with many craters resembling the craters of the Earth's moon. Many of these craters were formed when rocks crashed into the planet. Mercury also has many lava flows and quake faults on its surface. These craters, flows, and faults have shaped the surface of the planet.

Except for small amounts of helium and hydrogen, Mercury has no atmosphere. Scientists believe that Mercury has an iron core that extends through most of the planet. Mercury has significant temperature differences. Its daytime temperature reaches $800^{\circ} \mathrm{F}\left(427^{\circ} \mathrm{C}\right)$, while its nighttime temperatures reach $-300^{\circ} \mathrm{F}\left(184^{\circ} \mathrm{C}\right)$.

Pictures of Mercury's surface were first taken from
the Mariner 10 spacecraft that made flybys in 1974 and 1975, photographing about $45 \%$ of the surface of Mercury. The pictures displayed Mercury's many craters and loose, porous soil. It also gave indications that ice existed at its poles, in deep craters, where the Sun could not melt it. In the three Mariner 10 flybys, it was discovered that both a thin atmosphere and magnetic field existed.

In order to learn more about Mercury, NASA created the MESSENGER Program.Launched on August 2, 2004, MESSENGER conducted its first of three flybys of Mercury on January 14, 2008. Information collected from MESSENGER'S three flybys along with the key images taken from Mariner 10 helped to produce the first global map of Mercury in December of 2009. Beginning an orbital mission in 2011, MESSENGER is the first spacecraft to orbit Mercury. Through the MESSENGER Program, scientists will gain valuable information to better understand Mercury's geological history, extreme density, magnetic field, core, poles, and exosphere.

## Venus

Next, is Venus. It is the closest planet to Earth in both distance and size and is often referred to as Earth's sister. Venus is 67 million miles ( 0.7 AU ) from the Sun. It takes 225 days to revolve around the Sun. It is a very hot planet with temperatures in excess of $850^{\circ} \mathrm{F}\left(454^{\circ} \mathrm{C}\right)$. In fact, Venus is the hottest planet in the solar system.

Even with the heat, Venus is covered with clouds. These clouds are made of water vapor and sulfuric acid, and they rotate at a different rate than the planet. These clouds rotate every four


Venus days; much faster than the 243 Earth days it takes for Venus to rotate on its axis. By the way, Venus is the only known planet to rotate in a clockwise manner.

The atmosphere is $96 \%$ carbon dioxide and $4 \%$ nitrogen. There are also small amounts of water, oxygen, and sulfur. Scientists believe volcanic activity is responsible for the sulfur found in the atmosphere. Because of this thick layer of carbon dioxide and the clouds, the heat cannot escape. Therefore, there is very little temperature change on Venus.

The surface of Venus is a relatively smooth, hot desert. It does have some highlands and craters, too. Venus is the easiest planet to see at night and is the brightest of all. You can even see it in the daytime if you know where to look. Since it is the brightest planet that can be seen from Earth, Venus is referred to as the Evening Star. Venus has no moons.

Since Venus is the closest planet to Earth, it is also the most visited by our spacecraft. Mariner 2, 5, and 10 visited Venus, as did Pioneer 1 and 2. The USSR's Venera 9 and 10 also visited Venus.

The Magellan spacecraft, launched in May of 1989 aboard the Space Shuttle Atlantis, was sent to orbit Venus from 1990-1994. It collected radar images and was able to map more than $98 \%$ of the planet's surface. As a result of the mission, it was verified that volcanic materials cover most of Venus.

Venus continues to be visited by spacecraft. The Venus Express, a European Space Agency spacecraft that was launched in November of 2005, is scheduled to remain operational until 2012. Also, in the summer of 2010, Japan launched the Venus Climate Orbiter "Planet-C, " nicknamed "Akatsuki," which means "dawn."Akatsuki should reveal much detail about the climate and atmosphere of Venus. As explained by Japan Aerospace Exploration Agency (JAXA), "The Venus Climate Orbiter 'AKATSUKI' (PLANET-C) is the world's first planetary meteorological observation satellite to unveil the mysteries of wind on Venus. It will explore the mechanism of the Venus climate by observing the atmospheric movement and cloud formation process. "In learning about Venus, scientists also believe that they will develop a deeper understanding of Earth's environment: past, present, and future.

## Earth

As far as we know, Earth is the only planet that sustains life. Therefore, it is a unique planet. Earth is approximately 1 AU (93 million miles) from the Sun, and it takes the planet about 365 days to make one revolution around the Sun, which is one Earth year. Remember that the average distance from the Earth to the Sun is a straight line from the Earth to the Sun. The average distance that the Earth travels in its orbit around the Sun (circumference of Earth's orbit) is about 584 million miles $(939,856,896$ km ). If the Earth has to travel about 584 million miles to make a complete orbit around the Sun, and it takes about 365 days to do this, can you figure out about how fast the Earth is traveling around the Sun (not taking into account other factors such as


Earth Earth's wobble, one's location on Earth, etc.)? You are correct if you calculated about $66,700 \mathrm{mph}$ or 19 miles per second.

Besides speeding around the Sun, the Earth also moves by rotating on its axis. One day on Earth is the time it takes for the Earth to spin once on its axis, which is 24 hours. Because the Earth spins on its axis once every 24 hours, we experience day and night. If Earth's circumference at the equator is about 24,901 miles ( $40,074 \mathrm{~km}$ ), and it takes 24 hours for a point on Earth's equator to make one complete rotation, about how fast is


Tilt and seasons the Earth spinning on its axis? You are correct if you calculated a little over 1,000 miles per hour (or a little over a quarter of a mile per second).

Earth has four seasons because of the tilt of the Earth on its axis. Earth is tilted about $23.5^{\circ}$ on its axis. Because of this, different parts of the Earth receive different amounts of direct sunlight at different times of the year. For example, when the northern hemisphere experiences summer, the northern hemisphere is tilted more towards the Sun, and the rays of the Sun hit the northern hemisphere at a more direct angle. It, therefore, is not the distance between the Earth and the Sun that creates the seasons, but rather the tilt of the Earth on its axis.

Twice during the year, Earth experiences a solstice. A solstice occurs when the Sun is at its highest or lowest point in the sky. This occurs in the summer and winter. The summer solstice for the Northern Hemisphere occurs about June 21 and the winter solstice occurs around December 21. After the summer solstice, the hours we receive daylight slowly get fewer and fewer until we reach the winter solstice, which is the shortest day of the year in terms of daylight. After the winter solstice, the amount of daylight hours slowly increases until the summer solstice, which is the longest day of the year in terms of daylight hours.

Twice a year, the Earth experiences an equinox. An equinox occurs when the amount of daylight hours and nighttime hours are about the same due to the position of Earth in its orbit around the Sun, which causes the concentration of direct sunlight to be closest to the equator. The vernal equinox for the Northern Hemisphere occurs about March 21 and marks the beginning of spring. The days will continue to get longer in terms of daylight hours up until the summer solstice, which marks the beginning of summer. The autumnal equinox occurs about September 21 and marks the beginning of fall. The days will continue to get shorter in terms of daylight hours and cooler as the winter solstice draws near.

Our atmosphere contains $78 \%$ nitrogen and $21 \%$ oxygen, with small amounts of argon, carbon-
dioxide, neon, helium, ozone, and hydrogen. This atmosphere provides the oxygen that we breathe and keeps the temperature of water as liquid, so that life is possible. Our atmosphere also acts like a protective blanket. It contains clouds, and these clouds, along with the chemical composition of the atmosphere, help absorb some of the Sun's radiation.

A common question people have about Earth is, "Why is the sky blue?" NASA has an explanation that is fairly easy to understand. "The light from the Sun looks white, but it is really made up of all the colors of the rainbow. When white light shines through a prism, the light is separated into all its colors. Like energy passing through the ocean, light energy travels in waves, too. Some light travels in short, choppy waves. Other light travels in long, lazy waves. Blue light waves are shorter than red light waves. Sunlight reaches Earth's atmosphere and is scattered in all directions by all the gases and particles in the air. Blue light is scattered in all directions by the tiny molecules of air in Earth's atmosphere. Blue is scattered more than other colors because it travels as shorter, smaller waves. This is why we see a blue sky most of the time."

The surface of our planet is covered with over 70\% water, with the Pacific Ocean accounting for over $50 \%$ all by itself. Orbiting Earth is its one Moon, as discussed in the previous chapter. The Moon's gravity pulls on Earth and Earth's gravity pulls on the Moon. This mutual attraction is strong enough to pull the water in the Earth's oceans slightly towards the Moon, creating tides.

While $70 \%$ of Earth is covered in water, the remaining $30 \%$ is covered with various land features. The Earth has anywhere from smooth pastures, to plateaus and small hills, to tremendous mountains. We have lush forests and barren deserts. Our planet sustains not only human life, but plant life and animal life, too. From a variety of life forms to landscapes to climates, Earth is an interesting planet to study.

## Mars

Of all of the planets, Mars probably fascinates us the most. Over the years, it has been the most publicized in books and movies, and just about everyone knows it as the Red Planet. This is due to its red color which can be seen even with the naked eye. This color is due to the rock and dust covering the surface of Mars. It has been analyzed and found to have a high iron content, so it has a rusty look. Because of the decreased gravitational pull of Mars, the blowing dust on Mars rises easily, which also contributes to the atmosphere's reddish pink appearance.

Mars is about half as big as Earth and has about $1 / 9$ the mass of the Earth. Because its gravitational pull is about $1 / 3$ that of Earth's, objects weigh only about $1 / 3$ of what they weigh on Earth. For ex-


Mars ample, if something weighed 66 pounds on Earth, it would weigh about 22 pounds on Mars.

Mars has farther to travel around the Sun than Earth, but it takes about the same time as Earth to rotate once on its axis. The length of a Martian day is about the same as an Earth day at 24 hours 37 minutes. A Martian year is about 687 Earth days, which is about twice as long as an Earth year. How old are you on Mars? Divide your age by two for a close estimate.

Although the atmosphere of Mars is much less dense than Earth's, Mars has an atmosphere that supports a weather system. The atmosphere, which consists of $95 \%$ carbon dioxide, $3 \%$ nitrogen and traces of oxygen, carbon monoxide, and water, includes clouds and winds. Blowing dust storms occur periodically over the surface. Daytime surface temperatures near the equator on Mars can reach about $70^{\circ} \mathrm{F}\left(21^{\circ} \mathrm{C}\right)$, while nighttime temperatures can dip to $-130^{\circ} \mathrm{F}\left(-90^{\circ} \mathrm{C}\right)$. The average planet temperature is about $-80^{\circ} \mathrm{F}\left(-62^{\circ} \mathrm{C}\right)$. Although a cold planet overall, Mars does have four seasons due to the tilt of its axis, which is about $25^{\circ}$.

The surface of Mars is covered with deserts, high mountains, deep craters, valleys, and huge volcanoes. One of Mars's volcanoes, Olympus Mons, is the highest known mountain in our solar system. It is about 370 miles ( 595 km ) across and 17 miles ( 27 km ) high. (That is much taller than Mt . Everest which is about 5.5 miles high.) The largest known canyon in our solar system is Mars's Valles Marineras. It stretches over about $1 / 5$ the circumference of Mars, which is about 2,490 miles $(4,007 \mathrm{~km})$. If placed on the continental United States, it would stretch from the west coast to the east coast. Some parts of the canyon reach between four and five miles deep, compared to the Grand Canyon's lowest depth of about one mile (1.6 km).


Olympus Mons

Another geological feature on Mars is its polar ice caps. The polar ice caps are made of frozen carbon dioxide, or dry ice, and water ice. The water ice is located below frozen carbon dioxide. The ice caps wax (get bigger) and wane (shrink) with the seasons, waxing in winter and waning in the summer.

Orbiting Mars are its two small moons, Phobos and Deimos. Named after Greek mythological figures, their names translate to


Valles Marineras fear and panic. Scientists believe that these potato-shaped moons are actually asteroids that got captured by the gravitational pull of Mars. Phobos, slightly larger than Deimos, orbits closer to its planet than any other moon in our solar system, orbiting about 3,700 miles $(5,955 \mathrm{~km})$ from the planet. It is believed that in millions of years, Phobos might crash into Mars or break apart before it reaches Mars, resulting in smaller pieces of rocks orbiting Mars.

Mars's average distance from the Sun is approximately 141.6 million miles, which is about 1.5 AU. If you could drive to Mars when Earth and Mars are closest together, it would take about 66.5 years traveling at 60 mph . Depending on their positions in their orbits, the closest distance between Earth and Mars is about 35 million miles ( $56,327,040 \mathrm{~km}$ ), but they can reach a maximum distance of about 250 million miles $(402,336,000 \mathrm{~km})$. The distance between the two planets is critical to planning missions to Mars.

In the mid to late 1960 s, the Mariner spacecraft made flybys of Mars and took lots of photos. Pictures revealed Mars's surface to be like the Earth's Moon. Then in the mid 1970s another probe, Viking I, touched down on Mars. The primary mission of Viking I and Viking 2 was to determine if life ever existed on Mars. Unfortunately, the experiments were inconclusive even though more water


Sojourner Truth was found on Mars than had been expected.

In July 1997, the space probe called the Mars Pathfinder landed on Mars. The next day the Pathfinder's rover, Sojourner Truth, began its exploration of the planet. The Sojourner was two feet long and one foot tall. It studied the surface, analyzed the soil and rocks, and conducted scientific experiments on Mars.

Two other rovers, Spirit and Opportunity, landed on the Martian surface in January 2004. Their missions were extended for the fifth time in 2007. These rovers were able to study the geology of Mars, which provides great insight into explanations of the past and present environment of Mars. NASA reported, "Opportunity has returned dramatic evidence that its area of Mars stayed wet for an extended period of time long ago, with conditions that could have been suitable for sustaining microbial life. Spirit has found evidence in the region it is exploring that water in some form has altered the mineral composition of some soils and rocks. "Originally scheduled for a 90day mission, these rovers were still operating in 2010.

In July of 2008, a NASA spacecraft, the Phoenix Mars Lander, confirmed water on Mars. Phoenix had a scoop device that was able to dig up subsurface soil samples. It was also able to heat the samples and analyze them. "We have water," said William Boynton of the University of Arizona, lead scientist for the Thermal and Evolved-Gas Analyzer, or TEGA. "We've seen evidence for this water ice before in observations by the Mars Odyssey orbiter and in disappearing chunks observed by Phoenix last month, but this is the first time Martian water has been touched and tasted." Phoenix landed on Mars on May 25, 2008 in the northern polar plains and operated for five months, two months longer than scheduled. Its mission not only confirmed water ice on Mars, but also provided more insight into its climate, soil, and history.

Supporting both the Spirit and Opportunity rovers and the Phoenix lander is NASA's Mars Odyssey orbiter. Along with detecting water ice on Mars, the orbiter was launched in 2001 to map the chemical elements on Mars and collect radiation data, the Johnson Propulsion Laboratory (JPL) in Pasadena, CA reported that "infrared mapping showed that a mineral called olivine is widespread. This indicated the environment has been quite dry, because water exposure alters olivine into other minerals. "An instrument on the Mars Odyssey found that the Mars's radiation level is two to three times higher than that around Earth. In addition to these accomplishments, the Mars Odyssey helped study landing sites for Spirit, Opportunity, and Phoenix and provided communication relay support to them.

Other spacecraft have, are, and will study Mars in order to gain more insight into our neighbor, which some people believe may have the right ingredients for life. Next to Earth, it certainly has the most favorable conditions of any of the other planets in our solar system. Mars is the last in a line of what is considered the inner terrestrial planets.

## Jupiter

Jupiter is the first in the line of the outer, gaseous planets in our solar system. It is about 483.6 million miles from the Sun, which is about 5.2 AU . (Remember, 1 AU equals 93 million miles.) At its closest distance to Earth, Jupiter is about 500 million miles ( $804,672,000 \mathrm{~km}$ ) away. So, if you drove about 60 mph , it would take you hundreds of years, actually close to 1,000 years, to reach Jupiter.

Jupiter is the largest planet in our solar system. Its diameter is about 88,700 miles ( $142,749 \mathrm{~km}$ ). About 11 Earths could fit
 across the diameter of Jupiter. Jupiter is so big that if it were empty, every planet in our solar system could fit inside it. If you were only putting Earths inside it, it could hold about 1,320 Earths. Even though Jupiter is the largest planet in our solar system, it still isn't as big as the Sun. About 915 Jupiters could fit inside the Sun.

As far as mass, Jupiter's mass is so massive that it would take about 318 Earths to equal the mass of Jupiter. Although it has a huge mass, it has a low density because it is composed primarily of hydrogen, the lightest element. Jupiter's large size, huge mass, and low density create a gravitational pull on Jupiter that is about 2.5 times that of Earth's. So, an object weighing 100 pounds on Earth would weigh about 250 pounds on Jupiter.

A couple of other facts about Jupiter involve its revolution around the Sun, its rotation on its axis, and its temperatures. Jupiter revolves in almost 12 Earth years. Even though Jupiter is huge, it rotates on its axis very quickly, about every ten hours. This causes a flattening effect at the poles and a bulging effect at the equator. This fast rotation also enhances the weather patterns on Jupiter. It creates high winds and giant storms on Jupiter, where the temperature ranges from over $60,000^{\circ} \mathrm{F}$
$\left(33,316^{\circ} \mathrm{C}\right)$ at its center, to $-220^{\circ} \mathrm{F}\left(-140^{\circ} \mathrm{C}\right)$ at the upper cloud layers.
Jupiter is a gas giant. Hydrogen is the most prominent gas (about $90 \%$ ), followed by helium, methane, and ammonia. The outer core of Jupiter is composed of liquid hydrogen and helium, and these mix with the gaseous atmosphere to form belts of clouds. These belts are very colorful, but change rapidly due to the high winds associated with the quick rotation of the planet. These belts make Jupiter look like a striped ball with a giant red spot in the lower half. The Giant Red Spot is a distinguishing feature of Jupiter. This spot is a giant storm that is 30,000 miles $(48,280 \mathrm{~km})$ long and 10,000 miles ( $16,093 \mathrm{~km}$ ) wide.

A great deal of atmospheric activity on Jupiter is similar to that of Earth. However, Jupiter's storms seem to be powered by the planet itself rather than by the Sun, as they are on Earth. Jupiter's highly-compressed hydrogen at its center causes the planet to emit almost 70 percent more heat than it absorbs from the Sun. This leads scientists to speculate that the source of Jupiter's stormy turbulence is the planet itself.


To learn more about Jupiter and its moons, spacecraft have been launched toward this gas giant since as early as the 1970s. The Pioneer probes, launched in the 1970s, were the first to visit Jupiter. They discovered that the banded structure of the atmosphere was not present near the poles. The poles had a thick blue-sky atmosphere. Detailed studies showed rapid motions among the clouds and changes in the wind speeds. Beginning in 1979, Voyager probes were launched to study the outer planets. In 1979, Voyager 1 discovered rings around Jupiter. Jupiter's rings are dark and difficult to see, unlike those of Saturn. It was the spacecraft Galileo that revealed that the rings around Jupiter are formed by dust.
The Galileo mission was launched in October 1989 with the help of the Space Shuttle Atlantis. Its mission was to study Jupiter's atmosphere and moons. After flybys of Earth and Venus, it captured the first close-up picture of an asteroid in 1991 on its way to Jupiter. It also discovered the first known asteroid to have a moon, which was named Dactyl. It observed the comet Shoemaker-Levy crash into Jupiter in 1994. Galileo began exploring Jupiter and its moons in 1995. After several extensions of its mission, Galileo's journey finally came to an end on Sept. 21, 2003 after disintegrating in Jupiter's atmosphere. Galileo provided about 14,000 pictures and returned important information about Jupiter and its moons.

As of January 2009, Jupiter had 49 officially recognized moons with 14 other moons still being reviewed for "official" status. Ganymede, Callisto, Io, and Europa are the four largest moons of Jupiter. These four are called the Galilean moons, named after their human 1610 discoverer, Galileo.

The icy Ganymede Moon is the largest moon in our solar system. It is larger than the planet Mercury, but not quite as big as Mars. NASA's Galileo spacecraft indicated the presence of a magnetic field, making Ganymede the only known moon to have one. In 1996, the Hubble Space Telescope detected a thin atmosphere containing oxygen, but the atmosphere is too thin to support life.

Callisto is covered with craters, and, in 1999, the Galileo spacecraft detected a thin atmosphere of carbon dioxide.

Io also has a thin atmosphere, and it has active volcanoes that eject sulfuric acid. A NASA reference describes Io as "a giant pizza covered with melted cheese and splotches of tomato and ripe olives; Io is the most volcanically active body in the solar system. "NASA's Galileo spacecraft revealed that the volcanic activity on Io is 100 times greater than Earth's. With the exception of the vol-


Io
canic areas, Io has a very cold surface temperature.
Europa appears to be the smoothest celestial body in our solar system and has a weak atmosphere. "Europa's oxygen atmosphere is so tenuous that its surface pressure is barely one hundred billionth that of the Earth," said Principal Investigator Doyle Hall, of Johns Hopkins. "If all the oxygen on Europa were compressed to the surface pressure of Earth's atmosphere, it would fill only about a dozen Houston Astrodomes. It is truly amazing that the Hubble Space Telescope can detect such a tenuous trace of gas so far away." It is thought that there is a liquid ocean under Europa's icy surface. Based on the information returned from Galileo, it could have two times as much water as all of the oceans on Earth. Could organisms exist in that ocean?

Other outer planet spacecraft, such as Ulysses, Cassini-Huygens, and New Horizons, have flown by Jupiter on their way to other destinations. The next Jupiter-specific mission will be Juno which is scheduled to launch in 2011 and arrive at Jupiter in 2016. As part of NASA's New Frontiers missions, this polar orbiter will study Jupiter's atmosphere, magnetic field, inner structure, and polar magnetosphere.

## Saturn

About 887 million miles (or 9.5 AU ) from the Sun, Saturn is the sixth planet in our solar system and second in the line of outer, gaseous planets. Its diameter is about 74,898 miles ( $120,537 \mathrm{~km}$ ) across, meaning that about 9.5 Earths could fit across it. As the second largest planet in our solar system, Saturn could hold about 764 Earths inside it. Saturn, however, is the only planet in our solar system that is less dense


Saturn than water. This means Saturn could actually float in a body of water, if the body of water was large enough to hold Saturn. Objects weigh close to what they weigh here on Earth as the gravitational pull on Saturn is about 1.08 times that on Earth. So, if an object weighed 100 pounds on Earth, it would weigh 108 pounds on Saturn.

Like Jupiter, Saturn rotates at a very fast 10 hours. However, it takes over 29 years to revolve around the Sun. Also like Jupiter, the combination of fast rotation and gaseous and liquid atmosphere creates very strong winds, clouds, and storms. The winds of Saturn have been known to reach 1,100 miles per hour ( 1770 km ).

When we think of Saturn, we think of its rings. The rings are easily the most recognizable features of Saturn. Through a telescope, the rings are spectacular. They are made of ice chunks, dust, and rocks ranging from tiny particles to large boulders, or the size of grains of sugar to houses. The main rings are made up of hundreds of narrow ringlets. The entire ring system is about one mile thick and extends about 250,000 miles $(402,336 \mathrm{~km})$ from the planet. There are seven distinct rings, each designated by a letter ranging from A to G , around Saturn. The first five were discovered by Galileo in 1610, and the final two lettered rings were discovered by the Pioneer spacecraft. The Jet Propulsion Laboratory (JPL) and NASA also report that "there are also several other faint unnamed rings made up of very fine icy particles."

The planet itself has an icy rock core surrounded by metallic hydrogen with an outer layer of hydrogen and helium. The hydrogen and helium are mainly liquid and turn to gas as they get to the outer surface.

Being 9.5 AU from the Sun, the temperatures of Saturn do not vary as much as many of the other planets. During the day it gets up to $130^{\circ} \mathrm{F}\left(54^{\circ} \mathrm{C}\right)$ and at night, down to $-330^{\circ} \mathrm{F}\left(-201^{\circ} \mathrm{C}\right)$.

Pioneer and Voyager passed by Saturn in the late 1970s and early 1980s and produced much in-
formation about the planet. For instance, in was found that Saturn's outermost region contained its atmosphere and cloud layers. Saturn's three main cloud layers are thought to consist of (from top down) ammonia ice, ammonia hydrosulfide ice, and water ice.

To date, 62 moons have been identified orbiting Saturn, but only 53 of them have been named so far. Titan, one of Saturn's moons, is currently the only moon known to have clouds and a thick atmosphere. Its atmosphere is made up of about $95 \%$ nitrogen and $3-5 \%$ methane, along with some small amounts of other compounds. It has an orange, hazy sky, and its surface temperature is about $-289^{\circ} \mathrm{F}\left(-178^{\circ} \mathrm{C}\right)$. Its seasons, although all extremely cold, last about 7 years each.

We have learned, and continue to learn, a great deal about Saturn and its moons due to the Cassini-Huygens mission, a joint mission between the European Space Agency, the Italian Space Agency, and NASA. Launched in 1997, the spacecraft arrived at Saturn in 2004. The Cassini spacecraft did gravity-assist flybys of Venus and Earth, and performed a flyby of Jupiter as it traveled to Saturn at a speed of $70,700 \mathrm{mph}$. (If you drove 60 mph using the same path that Cassini took to get to Jupiter, about 2 billion miles, it would take you 5,600 years.) Scheduled to end in 2008, the project received two extensions, of which the second extension will keep its mission going until 2017.

In January 2005, the Huygens probe, which was bolted to the Cassini orbiter, detached from the Cassini orbiter and landed on Titan. This is the first time a probe landed on a celestial body in the outer solar system, and Titan is an interesting moon to study. NASA reported that "Huygens captured the most attention for providing the first view from inside Titan's atmosphere and on its surface. The pictures of drainage channels and pebble-sized ice blocks surprised scientists with


Titan, one of Saturn's moons the extent of the moon's similarity to Earth. They showed evidence of erosion from methane and ethane rain. Combining these images with detections of methane and other gases emanating from the surface, scientists came to believe Titan had a hydrologic cycle similar to Earth's, though Titan's cycle depends on methane and ethane rather than water. Titan is the only other body in the solar system, other than Earth, believed to have an active hydrologic cycle, and that is known to have stable liquid on its surface."

Remember, this liquid is not water; it is mostly methane, which, like water, can take the form of a gas, liquid, and solid. NASA and JPL's Cassini Web site reports that "methane, instead of water, forms Titan's clouds, rivers, and lakes. Cassini RADAR Team member Dr. Ralph Lorenz has determined that with Titan's low gravity and dense atmosphere, methane raindrops could grow twice as large as Earth's raindrops, and they would fall more slowly, drifting down like snowflakes. Scientists think it rains perhaps only every few decades, but when it rains on Titan, it really pours."

In a 2009 Space.com article, it was stated that "Saturn's moon Titan may be worlds away from Earth, but the two bodies have some characteristics in common: wind, rain, volcanoes, tectonics, and other Earth-like processes all sculpt features on Titan, but act in an environment more frigid than Antarctica. 'It is really surprising how closely Titan's surface resembles Earth's, 'said Rosaly Lopes, a planetary geologist at NASA's JPL in Pasadena, Calif. 'In fact, Titan looks more like the Earth than any other body in the solar system, despite the huge differences in temperature and other environmental conditions.' '"

In Feb. 2010, NASA reported, "Cassini's travel scrap-


Saturn
book includes more than 210,000 images: information gathered during more than 125 revolutions around Saturn, 67 flybys of Titan, and eight close flybys of Enceladus. Cassini has revealed unexpected details in the planet's signature rings, and observations of Titan have given scientists a glimpse of what Earth might have been like before life evolved."

## Uranus

Uranus is about 1.7 billion miles (19.18 AU) from the Sun, about twice as far as Saturn. Uranus is the first planet to be located with the help of a telescope, and it was discovered by an astronomer in 1781. It has only been since the mid 1980s that we have been able to increase our knowledge of Uranus. This was due to the US unmanned Voyager 2 mission which took the spacecraft on a flyby of Uranus in 1986.

Uranus is the third largest planet in our solar system, and, like Jupiter and Saturn, it is a gas giant. Uranus has a rocky core surrounded by water, ammonia, and methane, in both ice and liquid form.
 The outer layer consists of hydrogen and helium gases. There is also methane in the upper atmosphere, and this gives Uranus a bluish greenish color.

It takes Uranus 84 years to revolve around the Sun, and it rotates in about 18 hours. The average temperature is about $-350^{\circ} \mathrm{F}\left(-212^{\circ} \mathrm{C}\right)$ on Uranus. Its environment is super cold because hardly any solar radiation reaches Uranus. One unique thing about Uranus is that it spins on its side. Scientists think that possibly some large body may have bumped into it, resulting in its current position. Because Uranus is tilted $60^{\circ}$ on its axis, daylight lasts 42 years followed by 42 years of night. This means that even though the planet is rotating on its axis every 18 hours, it continues to face the sunlight for 42 years because of the $60^{\circ}$ tilt.

Like Saturn and Jupiter, Uranus has rings around it. It actually has 11 very narrow and black rings. They are made of dust and chunks of rock. They are very dark and hard to see. Additionally, Uranus has 27 known moons. These moons are made of rocks and ice, and many of the moons, such as Juliet, are named after characters in literature written by the famous English poet and playwright William Shakespeare. In 2005, the Hubble Space Telescope provided new images and information about Uranus's rings and moons.

## Neptune

Neptune is the outermost of the gas planets and is the fourth largest planet in our solar system. It was discovered in 1846 when scientists determined that something was affecting the orbit of Uranus. Neptune is about 3 billion miles ( 30 AU ) from the Sun, and it takes 165 Earth years to complete an orbit. So, one year on Neptune equals a little over 60,000 Earth days, or 165 Earth years. A Neptune day lasts about 19 hours. During the day, daylight on Neptune is about 900 times less bright than on Earth because Neptune is so far away from the Sun, making high noon on Neptune seem like a dim twilight.


Neptune and Uranus are so similar they are sometimes called twins. Although a bit smaller than Uranus, both Neptune and Uranus could each hold about 60 Earths inside them. Neptune's gravitational pull and average temperature are also very similar to that of Uranus. Neptune has a rocky core surrounded by water, ammonia, and methane. The atmosphere consists of hydrogen, helium, and methane. Methane absorbs red light, not blue; therefore, Uranus and Neptune appear to have a blue
tint, with Neptune's color being a bit more of a vivid, brighter blue. Regarding methane, pictures of Neptune show bright clouds of methane ice crystals are present. Like Uranus, we learned a great deal about Neptune thanks to Voyager 2.

Neptune is a windy planet, the windiest in our solar system. It has recorded winds of 1,500 miles per hour, which is close to the top speed of a F/A-18 Hornet, which is Mach 2. Storms similar to those on Jupiter were found during missions. Several large dark spots, or storms, were found during the Voyager missions. The largest of the storms, the Great Dark Spot, was about the size of the Earth. The original Great Dark Spot was gone when Hubble took photographs of Neptune in 1995.

Pictures indicate that Neptune has a very thin ring system, which is hard to detect. The ring system around Neptune is narrow and very faint. The rings are composed of dust particles that scientists believe were made by tiny meteorites smashing into Neptune's moons.

Neptune has 13 known moons, the largest of which is Triton. Triton is approximately threefourths the size of Earth's moon and circles Neptune in 5.875 days. The strange thing about Titan's movement is that it rotates backwards compared to the other moons of Neptune. Voyager 2 showed active geyser-like eruptions on Triton spewing invisible nitrogen gas and dark dust particles several kilometers into space.

Thinking about a manned mission to Uranus? You might change your mind after reading this information from JPL and NASA: "Trying to land on Neptune is a really bad idea. Like the other three giant planets, it is a big ball of gas that gradually becomes a hot liquid well below the clouds. There's nothing on which to land. Anyone foolish enough to drop below the cloud tops would be torn by intense winds, frozen by super cold temperatures, and eventually smashed by the sheer weight of the atmosphere above, which, by the way, is poisonous to humans."

## Pluto

A planet or not a planet? That is the current scientific question. Astronomer Clyde Tombaugh discovered Pluto in February 1930. Pluto remained our official ninth planet until 2006 when the International Astronomical Union (IAU) changed the definition of "planet." Pluto then no longer met all of the requirements to stay in the same league as the other eight planets. Pluto was removed from "classical planet" status because it did not meet one of the new require-


Poor Pluto
Credit: MathiasPedersen.com ments needed to be a planet. That requirement is that the object must dominate its orbital path. Pluto's orbit actually crosses Neptune's, and Pluto orbits in an area of icy rock bodies called the Kuiper (pronounced KY-per) Belt. The Kuiper Belt is located beyond Neptune's orbit and reaches a little past the outermost point of Pluto's orbit to the edge of our solar system.

Pluto was reclassified as a dwarf planet. A dwarf planet is "a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass to assume a hydrostatic equilibrium (nearly round) shape, (c) has not cleared the neighborhood around its orbit, and (d) is not a satellite." About two years after being demoted to dwarf planet, the IAU created a special class of dwarf planets known as plutoids, which includes and is named after Pluto. Plutoids are dwarf planets that are located beyond Neptune. All plutoids are dwarf planets, but not all dwarf planets are plutoids. For example, between Mars and Jupiter, there is a dwarf planet called Ceres. It is not a plutoid because it is not located beyond Neptune, as is the case with Pluto.

An interesting characteristic about Pluto is its strange orbit. It is more elongated than any of the
other traditional planets, and sometimes is actually closer to the Sun than Neptune. For about 20 of 248 Earth years (or just a little over $1 / 12$ of a Pluto year), Pluto's orbit cuts inside Neptune's, making it closer to the Sun than Neptune. The last time Pluto's orbit was inside Neptune's was from 1979-1999. The next time that will happen will be about the year 2227.

When classified as a planet, Pluto was the smallest of all of the planets in our solar system. Pluto's diameter is about $2 / 3$ that of Earth's moon, and Pluto is almost 4 billion miles ( 39.53 AU ) from the Sun. Pluto rotates once on its axis in about 6.5 Earth days. A


Pluto year on Pluto is about 248 Earth years.

Pluto is a yellowish plutoid that is dark and frozen. The Sun would appear as a bright shining star in the sky, and the average temperature on Pluto is estimated to be about $-350^{\circ} \mathrm{F}\left(-212^{\circ} \mathrm{C}\right)$.

Pluto is believed to have a rocky core with a water and ice layer above the core. The surface is made up of methane frost.

Hydra, Nix, and Charon are Pluto's three known moons. (Yes, dwarf planets can have moons.) Charon is half the size of Pluto, making it difficult to tell the two apart. Charon's rotational period is the same as Pluto's, so they travel in synchronous orbit together. However, they spin in opposite directions.

So little is known about Pluto and other plutoids, such as Eris, MakeMake (pronounced MAH-kee-MAH-kee), and others because they are so far away from Earth. Much of what we know is because of Earth-based observations and the Hubble Space Telescope. We hope to learn more about these objects and the outer edge of our solar system, and we are counting on the New Horizons orbiter to help us. The New Horizons piano-sized spacecraft was launched in 2006. It will reach Pluto in 2015 and spend time studying Pluto and its moons before traveling further out to study other objects in the Kuiper Belt.

## Summary

We have eight planets and a number of dwarf planets that make up our solar system. Our solar system includes so many objects: our Sun, planets, and moons. It also includes other celestial bodies such asteroids, comets, and meteoroids. Our solar system is just a small part of our galaxy which is just a small piece of the great big universe. (See associated Activity Fourteen and Fifteen at the end of the chapter.)

## ACTIVIT) ${ }^{\text {S }}$ SECTION <br> 

## Activity Fourteen - How Old Are You?

Purpose: Use math skills to determine your age on other planets

Materials: chart provided, pencil, paper, and calculator

## Procedures:

1. Calculate your age in Earth days. One year $=365$ days.
2. Calculate your age in Earth days for the other planets in the solar system.
3. Then convert the Earth days into Earth years. Example: 14 years old on Earth $=365 \times 14=5110$ Earth days.

Summary: No two planets in our solar system take the same amount of time to make one revolution around the Sun; therefore, a person's age on Earth would not be the same if he/she lived on another planet. For example, a person who was 12 Earth years old (4,380 Earth days) would be almost 50 years old on Mercury and just a little over 1 year old on Jupiter.

| Earth | one year $=365$ days |
| :--- | :--- |
| Mercury | one year $=88$ Earth days |
| Venus | one year $=243$ Earth days |
| Mars | one year $=687$ Earth days |
| Jupiter | one year $=11.5$ Earth years |
| Saturn | one year $=29.5$ Earth years |
| Uranus | one year $=84$ Earth years |
| Neptune | one year $=165$ Earth years |

## Activity Fixteen - Creating a Clay Model of the Solar System

Purpose: Use math skills and clay to create a visual scale model of the Solar System.
Materials: 8 index cards, marker, 3 pounds of clay (or dough)
Procedures: Using a marker, label the 8 index cards with the names of the 8 planets. Then using 3 pounds of modeling clay, follow the 7 steps listed below.
Step 1. Divide the clay into 10 equal parts (tenths).

- Use 6 tenths to make Jupiter.
- Use 3 tenths to make Saturn.
- Use the remaining clay (1 tenth) in step 2.

Step 2. Divide the remaining clay into tenths.

- Add 5 tenths to Saturn.
- Use 2 tenths to make Neptune.
- Use 2 tenths to make Uranus.
- Use the remaining clay (1 tenth) in step 3.

Step 3. Divide the remaining clay into fourths.

- Add 3 fourths to Saturn.
- Use the remaining clay ( 1 fourth) in step 4.

Step 4. Divide the remaining clay into tenths.

- Use 2 tenths to make Earth.
- Use 2 tenths to make Venus.

Check your work!
When you finish making your 8 planets, you should double-check your work!

Use a metric ruler to measure the diameter of your clay planets in millimeters ( mm ).

The diameter of your planets should be close to the "scale diameter" measurements in the chart.

- Add 4 tenths to Uranus.
- Combine the remaining clay ( 2 tenths) and use in step 5.

Step 5. Divide the remaining clay into tenths.

- Use 1 tenth to make Mars.
- Add 4 tenths to Neptune.
- Add 4 tenths to Uranus.
- Use the remaining clay ( 1 tenth) in step 6.

Step 6. Divide the remaining clay into tenths.

- Use 7 tenths to make Mercury.
- Add 2 tenths to Uranus.
- Use the remaining clay (1 tenth) in step 7.

Step 7. Divide the remaining clay into tenths.

- Add 9 tenths to Uranus.

Summary: No two planets are exactly the same size. This activity makes it easy to compare and contrast the size of the planets in our solar system to one another.

| Object | Actual <br> Diameter <br> $(\mathrm{km})$ | Scale <br> Diameter <br> $(\mathrm{mm})$ | Distance <br> from Sun <br> $(\mathrm{AU})$ |
| :--- | :---: | :---: | :---: |
| Sun | $1,391,900$ | 993 | - |
| Mercury | 4,878 | 3.5 | 04 |
| Venus | 12,104 | 8.6 | 0.7 |
| Earth | 12,755 | 9.1 | 1.0 |
| Mars | 6790 | 4.8 | 1.5 |
| Asterold | 1101,000 | 0.0007 10 |  |
| Belt | 0.7 | 2.0104 .0 |  |
| Jupiter | 142,796 | 102 | 5.2 |
| Saturn | 120.660 | 86 | 9.5 |
| Uranus | 51,118 | 36 | 19.2 |
| Neptune | 49.528 | 35 | 300 |

