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Dear Teachers,

Welcome to the Astronomy Student Program! The Student programs are designed to connect teachers and students to science by providing interdisciplinary curriculum resources and fieldtrip programs.

In this packet you will find:

- Pre and post-visit activities to use in your classroom
- Content and logistical information on the student fieldtrip program
- At-museum information for exploring Astronomy during the field trip
- Other Resources & References to use in your classroom

The Astronomy program is designed to help bridge classroom curriculum to the museum fieldtrip experience by connecting to the 3rd - 5th grade earth sciences, mathematics, language arts, creative expression, and investigation and experimentation standards. Research has shown that when students have some prior learning of a topic before a field trip, they will better be able to incorporate new ideas into their prior knowledge. Therefore, the enclosed materials are intended to prepare you and your students for the field trip experience.

Thank you for choosing to participate in the program. If there is anything that I can do to help you plan your trip or improve the programs that we offer, please don't hesitate to contact me!

Happy Exploring,

Lindzy Bivings

Manager
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Teacher Resource Guide

Astronomy Field Trip Program

Grades 3 – 5

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Arthur and Toni Rembe Rock Fund.
www.calacademy.org/teachers/rockprogram

CALIFORNIA ACADEMY OF SCIENCES

Teacher Resource Guide

Astronomy

Grades 3 – 5

Contents

Recommended Activity Flow

For optimal student learning, we recommend using the activities provided in this Teacher Resource Guide in the following order:

Pre-visit activities: Worlds in Comparison and Pocket Solar System

When students are learning about the solar system, understanding the vast distances and scales involved can be challenging. In these activities, students will demonstrate the relative sizes of and distances to the planets of the solar system by creating scale models in paper and clay.

At-museum activity: Field Trip Program: A Tour of Our Solar System

During their field trip, students will participate in a 40-minute live planetarium program presented by California Academy of Sciences educators. The program includes observation and discussion of celestial objects as seen from Earth, visualizations of the motions of the planets, and a virtual tour of the solar system.

At-museum activities: Foucault Pendulum, Solar System Mural, Moon Rock and Meteorite

While visiting the California Academy of Sciences' Islands of Evolution and Earthquake exhibits, students will be able to observe the motion of a pendulum (demonstrating the rotation of Earth), touch a fragment of an iron asteroid that impacted Earth 49,000 years ago, and view a rock brought back from the Moon by Apollo 17 astronauts in 1972.

Post-visit activities: Kinesthetic Astronomy: Earth's Rotation, The Meaning of a Year, and Mars Opposition Dance

Many people have a hard time interpreting drawn diagrams and understanding how planets move in relationship to the sun. Kinesthetic activities use physical movements to connect students to the astronomical concepts explored during their field trip. In these activities, students will turn themselves into planets and then physically move their bodies and engage in critical thinking in order to understand how Earth rotates and planets orbit the Sun.

Field Trip Program: A Tour of Our Solar System

GRADE LEVEL	3^{rd} - 5^{th}
SUBJECTS	Earth Sciences, Investigation & Experimentation
DURATION	Activity: 40 minutes
SETTING	Morrison Planetarium at the California Academy of Sciences

Objectives

1) Students learn that the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons. Other objects move more rapidly in the night sky and are not stars; they are objects in our solar system.
2) Telescopes magnify the appearance of some of these objects, including the Moon and the planets. The use of the telescope changed our understanding of the cosmos.
3) Our Sun is an average star, the central and largest body in the solar system and is composed primarily of hydrogen and helium.
4) The solar system includes the planet Earth, the Moon, the Sun, seven other planets and their satellites, and smaller objects such as asteroids, comets and dwarf planets.
5) The planets of the solar system fall into two broad categories: small rocky planets with few satellites, and large gaseous planets with many satellites and ring systems.

Summary

The state-of-the-art Morrison Planetarium uses the latest scientific data and visualization techniques to chart our course to the edge of the solar system. The presentation will discuss: the definition of our solar system, common constellations (including the Zodiac), objects in the sky other than stars (meteors, comets, planets), what a planet is, gravity and motion, a close-up on each of the planets, similarities and differences between planets, important regions in our solar system (Asteroid Belt, Kuiper Belt), and a study of our planet and its peculiar habitability.

Correlated California Content Standards

Grade Three

Physical Sciences

1 a. Students know energy comes from the Sun to Earth in the form of light.

Earth Sciences

4a. Students know the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.

4c. Students know telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye.

4d. Students know that Earth is one of several planets that orbit the Sun and that the

Moon orbits Earth.
4e. Students know the position of the Sun in the sky changes during the course of the day and from season to season.

Grade Five

Earth Sciences

5a. Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.
5c. Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Correlated New California Content Standards

First Grade

1-ESS-1. Use observations of the sun, moon and stars to describe patterns that can be predicted.

Fourth Grade

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

Fifth Grade

5-ESS-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.
5-ESS-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Middle School

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

Field Trip Program Outline

Introduction

- Students are welcomed to the Morrison Planetarium by a planetarium educator, who will use the planetarium's visualization capabilities to pilot them on a tour of our Solar System.
- Students are encouraged to engage the presenter during the presentation as we discuss the variety of objects seen on our tour.

Importance of the Sun

- Students are transported out into Golden Gate Park to view the motion of the Sun.
- The Sun provides the energy that makes life on Earth possible; its position in the sky varies from season to season.
- Our Sun is a typical star, made mostly of hydrogen and helium gas; we study the Sun to learn about the composition and nature of stars.

The Night Sky: Stars, Comets, Meteors and Planets

- We illustrate the rotation of the Earth, bringing the night sky into view. Students will explore star patterns visible in the sky during the season of their visit.
- City lights block all but the brightest stars from view; we transport ourselves to a dark sky location to view the Milky Way and constellations.
- The stars can be observed in fixed patterns, night after night; other objects – comets, meteors – are seen more fleetingly.
- Planets move more slowly, wandering through that part of the sky marked by the constellations of the Zodiac.
- Galileo's use of the telescope to study the sky revolutionized our understanding of these objects and began the age of astronomical discovery.

Gravity and the Motion of the Planets

- We launch ourselves into space to view the motion of Earth and the inner planets around the Sun.
- The Sun contains most of the mass in the Solar System, and its gravity affects the orbital motion of the planets.
- Closer objects to the Sun move faster to overcome the Sun's stronger gravitational influence.

The Inner Solar System

- We visit each of the four terrestrial planets in turn, describing their orbital periods, material composition, atmospheres, surface features and satellites.
- The similarities and differences among these worlds are discussed.

The Outer Solar System

- We pull away from the Sun to view the asteroid belt and discuss the small rocky bodies found there.
- Another leap outward brings into view the four outer planets, orbiting much farther from the Sun.
- The four gas giant planets are visited in turn, highlighting their common features: composition, number of satellites and ring systems. These are contrasted with the rocky inner planets.

Dwarf Planets and the Kuiper Belt

- A final leap takes us to an overview of the solar system as a whole.
- The eight planets share similar orbits in a flat plane; beyond Neptune lies a region called the Kuiper Belt, filled with small icy bodies in irregular orbits.
- Pluto is typical of a new class of objects called dwarf planets, several of which are members of this region.

Earth: Island of Life

- We return to Earth, passing the orbits of the eight planets in turn.
- Our planet, in contrast to the other worlds we've visited, has substantial quantities of water on its surface – a condition that is unique in the Solar System.
- Life on Earth depends on liquid water; we see examples of the variety of life and discuss the importance of protecting our planet.

Field Trip Logistics & Exhibit Connections

When you arrive at the California Academy of Sciences a guest services staff member will greet your class at the bus or when you walk up. They will check you in and lead your class into the museum.

Where is my program? Once inside the museum, you will need to go to the Planetarium entrance on Level 1, near the giraffe exhibit on the southeast side of the main exhibit hall. You should plan to arrive at the Planetarium no later than 15 minutes before your scheduled show time. Your group will be admitted into the Planetarium and seated together; be aware that you will be sharing the planetarium with other school groups that may be attending the program that day.

Where else should I go in the Museum?
If you have extra time before or after your visit, we highly recommend you spend some time in the exhibits. It is unrealistic to see every exhibit during the field trip and so we recommend choosing a few to go to. The exhibits that connect to the field trip program are listed below. You may come preview the exhibits for free before your field trip. Just show your field trip confirmation at the door.

Islands of Evolution: The south wall of this exhibit contains a timeline of Earth's evolution, beginning with the birth of the Solar System 4.5 billion years ago. Here you will find one of the rarest objects on Earth: an actual sample of a moon rock, brought back by the Apollo 17 astronauts in 1972.

Solar System Mural: This mural, located outside of the Forum Theater on Level 2, exhibits the major objects in the solar system, i.e. the Sun, eight planets, and some significant moons. Planets (which are grouped into ***inner planets*** and ***outer planets*** based on their size, composition and distance from the sun) are illustrated in a way to fairly demonstrate the relative sizes of the planets and their moons in comparison to the size of the sun. An adjacent illustration shows the relative distances between the planets. The traditional symbols designated to each planet are also displayed next to each one.

Earthquake: This exhibit discusses the evolution of Earth's continents through the process of plate tectonics, a process that has continued through billions of years of Earth's history. In the entry area of the exhibit, you will find a 221-pound piece of the Canyon Diablo iron meteorite from Barringer crater in Arizona.

Foucault Pendulum: A returning favorite from the original Academy, the Foucault pendulum provides simple and elegant proof of the Earth's rotation. Suspended from the ceiling next to Morrison Planetarium, it consists of a 235-pound brass ball attached to a 30-foot-long steel aircraft cable. The plane of the pendulum's swing appears to rotate 220 degrees every day. Since no rotational forces act on the pendulum, it must be the Earth beneath that is actually rotating.

Background Information

The Academy's Moon Rock

The 1969-1972 Apollo missions mark the first and (to date) only steps taken by humans onto another world beyond Earth – our Moon. The stark images brought back from the Moon sharply illustrated the differences between that lifeless body and our life-sustaining blue planet. But the samples of lunar material brought back by the Apollo astronauts suggest that the Moon shares a common origin with Earth – a violent origin.

Our planet's only natural satellite is thought to have formed when an object about the size of Mars collided with Earth some 4.52 billion years ago – about 50 million years after the formation of the Solar System. Most of the impacting object eventually ended up on Earth, but a percentage of ejected material from this collision went into orbit around Earth and coalesced to form the Moon. Having such a large satellite has influenced our planet's evolution, by helping to stabilize Earth's axis and creating tides in Earth's oceans. Those forces work on the Moon, as well.

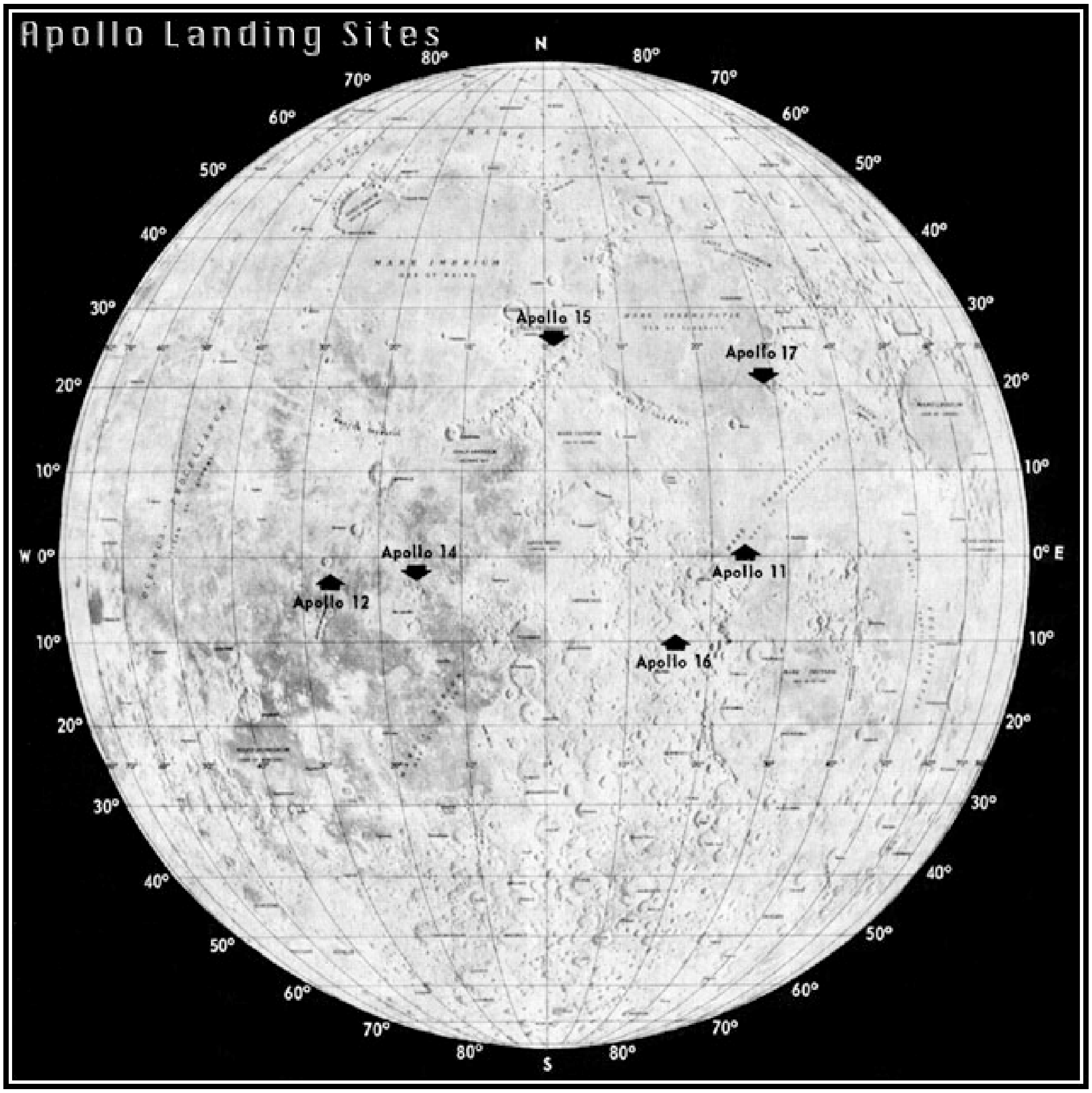
The Moon is 3,474 km (2159 miles) in diameter, or about a quarter of Earth's diameter, and it orbits about 384,400 km (239,000 miles) from Earth. This combination of lower mass and relative nearness has caused the Moon to fall into a synchronous rotation as it orbits Earth; that is, it rotates once on its axis in the same time it takes to complete one orbit. As a result, we see only one side of the Moon from Earth.

The Apollo Missions

In order to maintain line-of-sight communication with Earth, all six Apollo missions landed on the visible, near side of the Moon.

Other safety factors influenced the selected landing sites. Topography and texture of the lunar surface were important for safe landing – the slope could not be too great nor the craters too numerous. The position of the Sun in the sky was also important, so that the astronauts could see to land without too many shadows, but with enough contrast to see details of the surface.

The scientific objective of procuring sample materials representative of different terrains and geologic history played another significant role in the selection of landing sites, particularly for the final three missions. These missions included the use of a Lunar Roving Vehicle (LRV), which allowed the astronauts to extend the range of their surface extravehicular activities.



The Apollo program returned 381.7 kg (841.5 lb) of rocks and other material from the Moon. Three Soviet Luna spacecraft returned an additional 0.32 kg (0.7 lb) of samples (and almost 50 kg of meteorites found on Earth have been identified as being of Moon origin).

Lunar Samples

The Moon has two major types of terrain, with corresponding categories of rock:

- Highlands are rough and mountainous – the rocks, whiter in color, are largely igneous rocks called anorthosites.
- Maria (Latin for “seas”) are dark low-lying areas – these are flooded basalt plains, formed when lava flowed into large impact basins.

Basalt covers 26% of the near side of the Moon, while the far side contains very few maria. It remains unclear why this distinction exists.

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The Academy's sample was collected during the Apollo 17 mission in 1972, by astronaut Harrison "Jack" Schmitt. He was the only trained geologist to take part in an Apollo mission to the Moon.

Apollo 17

The final Apollo mission to the Moon landed in the Taurus-Littrow highlands and valley area, on the southeastern rim of Mare Serentatis on December 12th, 1972. This site was picked as a location where rocks both older and younger than those previously returned from other Apollo missions and the Luna 16 and 20 missions might be found.

Apollo 17 achieved a number of lunar firsts:

- Longest Apollo mission – 301 hours, 52 minutes
- Longest single extravehicular activity (EVA) time on the surface – 7 ½ hours
- Longest total EVA time on the surface – 22 hours
- Greatest Lunar Rover Vehicle distance on one EVA – 19 kilometers (14 miles), and total distance traveled – 35 kilometers (25 miles)
- Largest number of lunar samples returned to Earth – 117 kilograms (257 pounds)

Parent Rock

NASA photo # S72-56385

The Academy's specimen is a small piece of lunar sample 70035, a medium-grained, high-titanium basalt weighing 5.765 kg (12.71 lb).

As described in the Lunar Sample Compendium (C. Meyer, 2008):

> It was collected from a boulder on the rim of a subdued crater about 45 meters east northeast of the Lunar Module. This large sample was not "oriented". The bottom surface of this sample is coated with glass. One side is flat. The other surfaces are rounded and have micrometeorite pits. 70035 is 3.7 billion years old and has been exposed on the lunar surface for ~ 100 million years. It is typical of the high Ti basalts from the moon and has been used for several public displays.

Note: The glass in lunar rocks is naturally occurring, not added to the sample. It is a common component of lunar samples, resulting from volcanism or impact heating.
According to the Apollo 17 Catalog (Butler 1973; page 39), 70035 was opened in the Command Module and studied by Jack Schmitt who picked it up with bare hands (permission granted).

NASA S84-34617

Sample 70035 was dissected into smaller pieces and thin slices for scientific study and public display. The Academy's sample is designated 70035,69, and weighs 102.58 grams (3.6 ounces). It is one of nine pieces from sample 70035 on display. It is composed of ilmenite basalt – similar to basalts found on Earth, although with a higher iron content. It is stored in nitrogen gas to prevent oxidation through interactions with water vapor or oxygen in our atmosphere. The rock can only be touched with Teflon or stainless steel, in order to prevent contamination.

http://science.ksc.nasa.gov/history/apollo/apollo-17/apollo-17.html
http://curator.jsc.nasa.gov/lunar/
http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_lrv.html

The Solar System

While the planetarium is very good at illustrating the relative distances to these solar system objects, it is less effective at demonstrating that some planets we visit are much larger than others (without artificially placing them next to each other in space). The following information can serve as an effective adjunct to the planetarium program to reinforce these concepts.

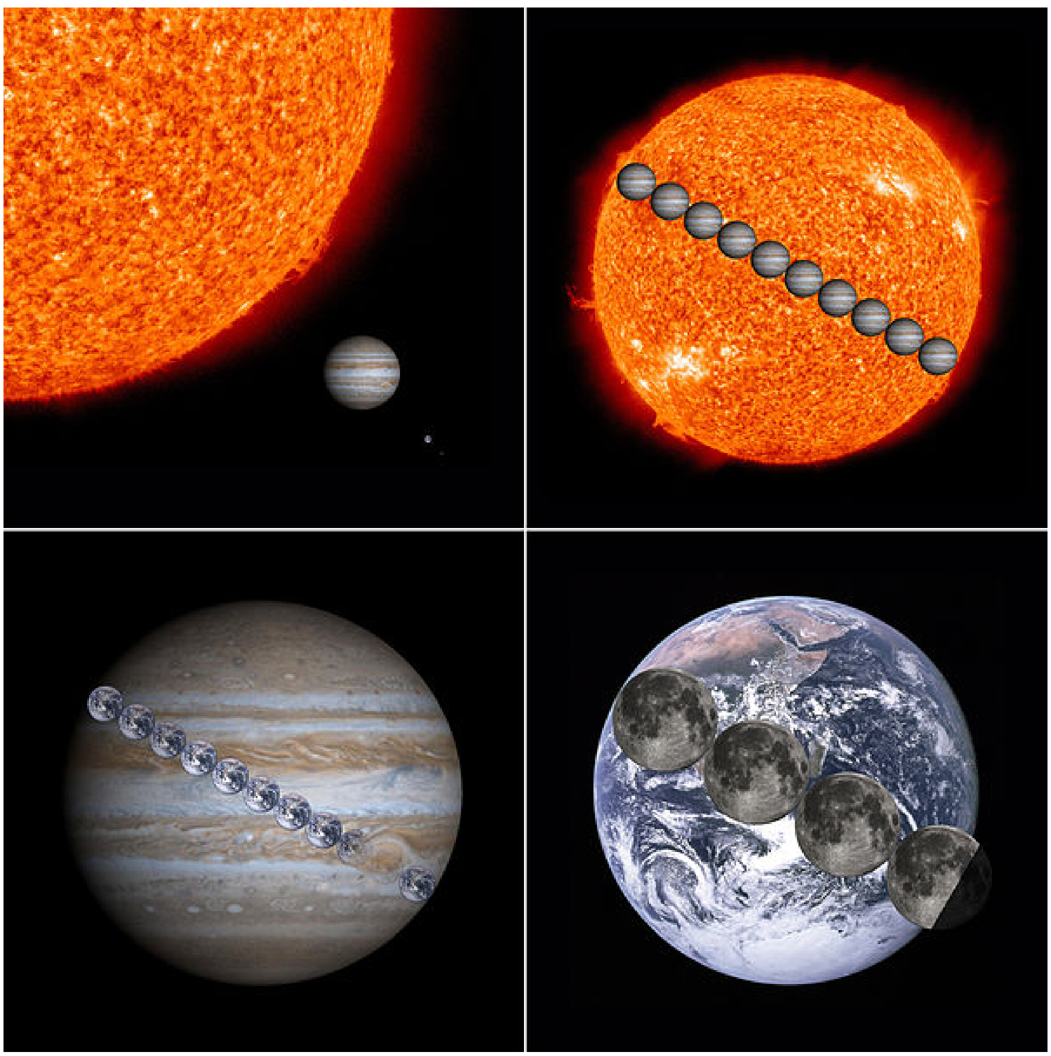
The Sun is by far the largest object in the solar system, containing over 99% of the total mass and having a diameter 10 times that of the largest planet, Jupiter.

Comparative sizes of Sun, Jupiter, Earth and Moon:

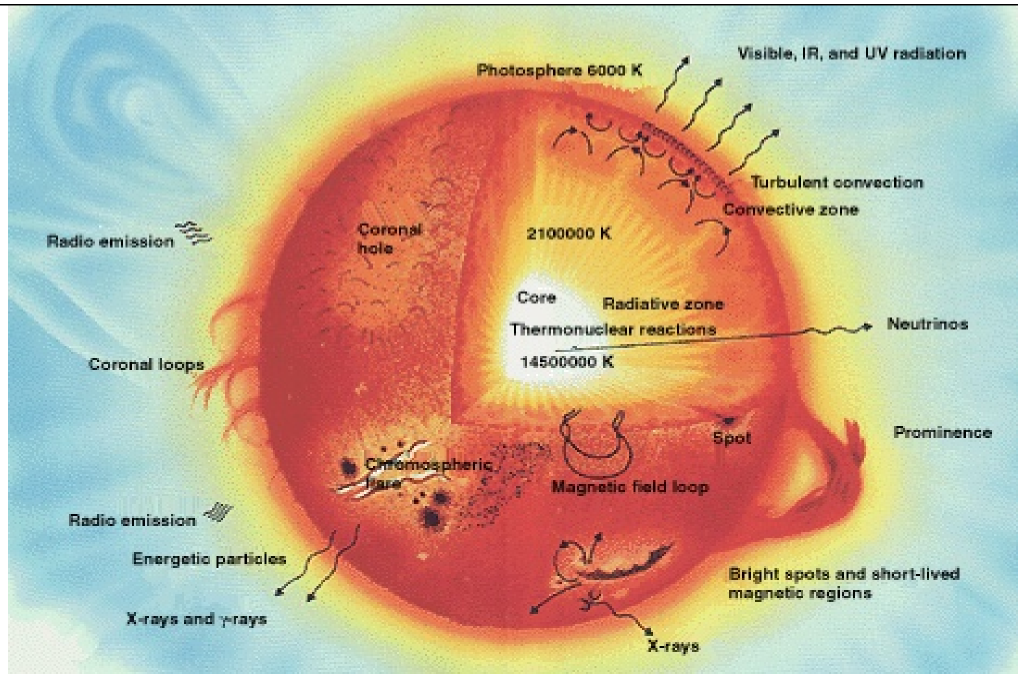
Sun= 10 Jupiter diameters

Jupiter=11 Earth diameters

Earth= 3 and ¾ Moon diameters



The following tables show the major characteristics of the sun and planets.

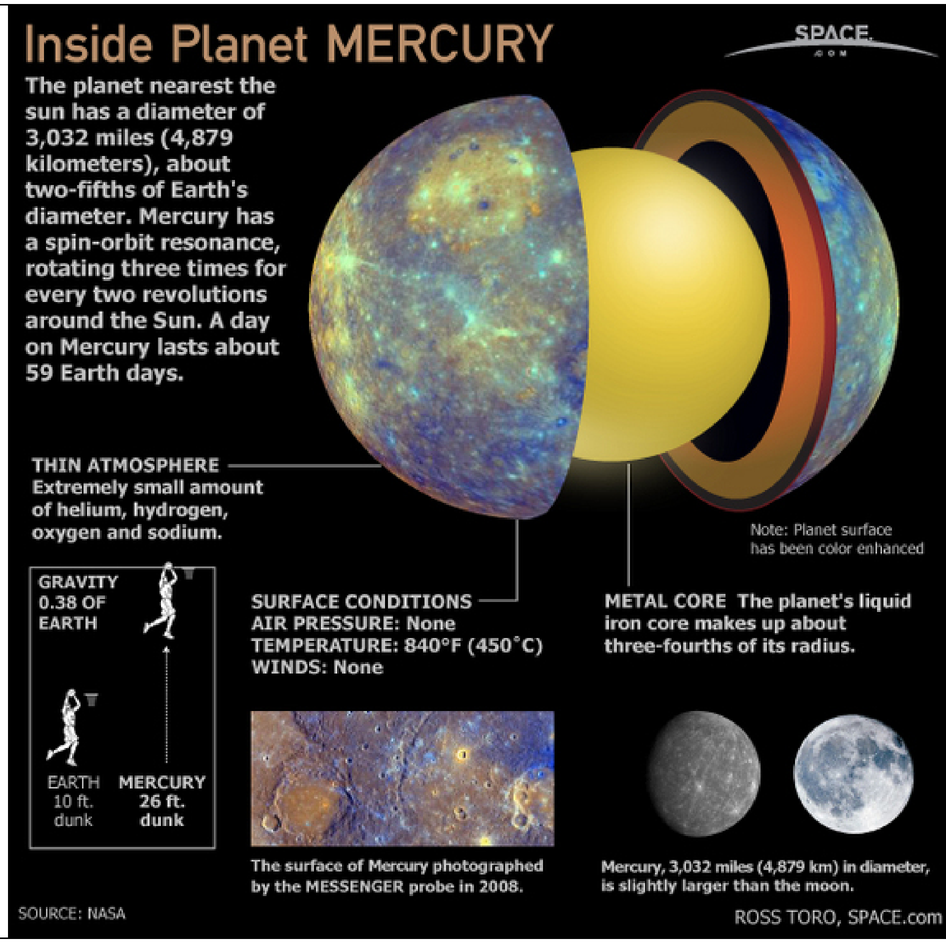
<table>
<tr><td colspan="1">Sun
⊙</td><td colspan="2">

The Sun consists of six parts:
1. The core is the center. This is where hydrogen is converted into helium via nuclear fusion.
2. The radiation zone is above the core.
3. The convection zone is the outer part of the Sun's interior.
4. The photosphere is above the convection zone and is the part of the Sun that we see.
5. The chromosphere is above the photosphere. During solar eclipses it can be seen when the much brighter photosphere is blocked out by the Moon.
6. The corona is the outermost layer of the Sun. It is the hottest part of the atmosphere of the Sun. It extends millions of kilometers into space and is a million times fainter than the photosphere. It has temperatures reaching millions of degrees. The corona can be seen only during solar eclipses because it is millions of times fainter than the photosphere. Specially designed scientific instruments called coronagraphs can also observe it.</td></tr>
<tr><td>Diameter</td><td>870,000 miles (1.4 million km), 109 times larger than the Earth's</td><td>The Sun is big enough to contain over 1 million Earths</td></tr>
<tr><td>Temperature</td><td colspan="2">10,000°F (≈ 5600°C) at surface and 27,000,000°F (15,000,000°C) at the center</td></tr>
<tr><td>Distance from the Earth</td><td colspan="2">93,000,000 miles (149 million km). It takes light 8 and 1/2 minutes to travel from the Sun to the Earth</td></tr>
<tr><td>Composition</td><td colspan="2">Sun's composition: 70% hydrogen, 28% helium, 1.5% carbon, nitrogen, and oxygen, and 0.5% all other elements</td></tr>
</table>

Mercury

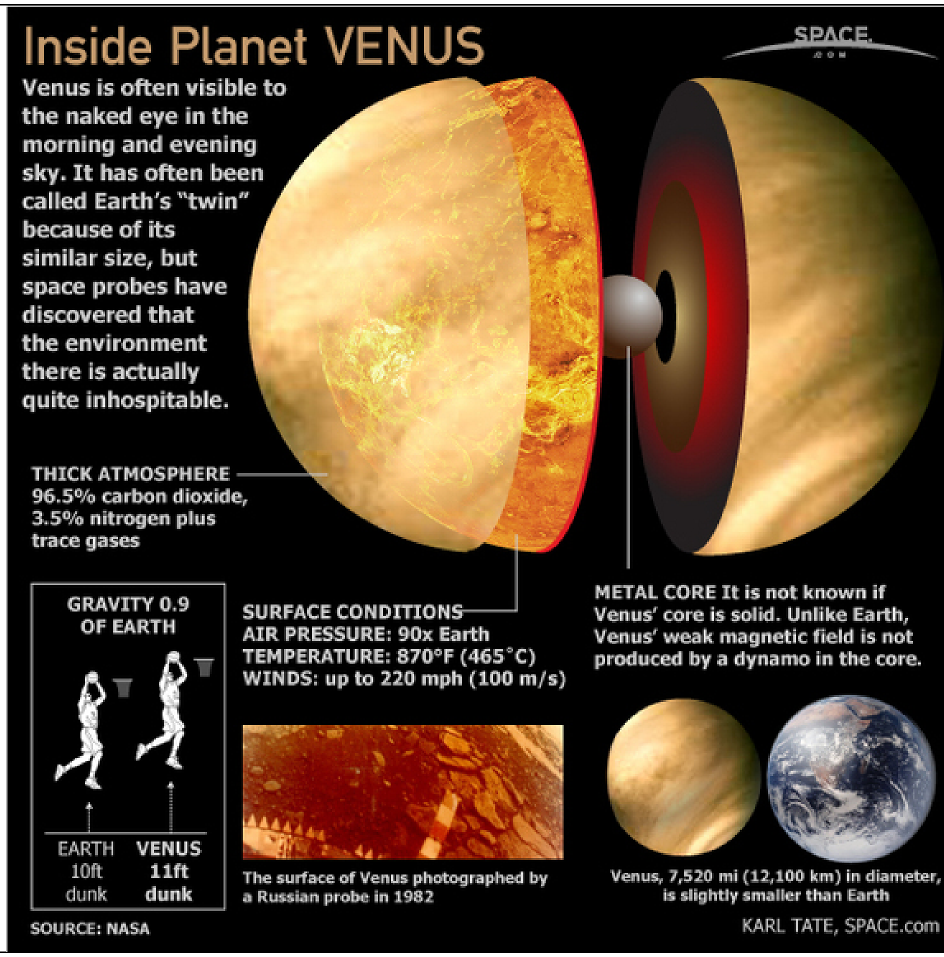
☿

The messenger god of the Romans



☿	**Symbol represents**: winged helmet and staff (caduceus)	
Diameter	3,032 miles (4,878km) at its equator. About 2/5 of Earth's diameter	
Temperature	Day: may reach 450° C (840° F) during the day	Night: as low as -170°C (-275°F)
Average distance from the sun	About 36 million miles (58 million km)	
Orbiting the sun	Every 88 days	
Distance from Earth	48 million miles (77 million km) at closest distance	
Mass	3.30e23 kg (5.5% of Earth's)	An object that weighs 100 pounds on the Earth would weigh only about 38 pounds on Mercury.
Composition	Atmosphere: none	
Moons	0	
Exploration	Flybys by the Mariner 10 spacecraft in 1974 and 1975, Messenger probe twice in 2008 and once in 2009.	

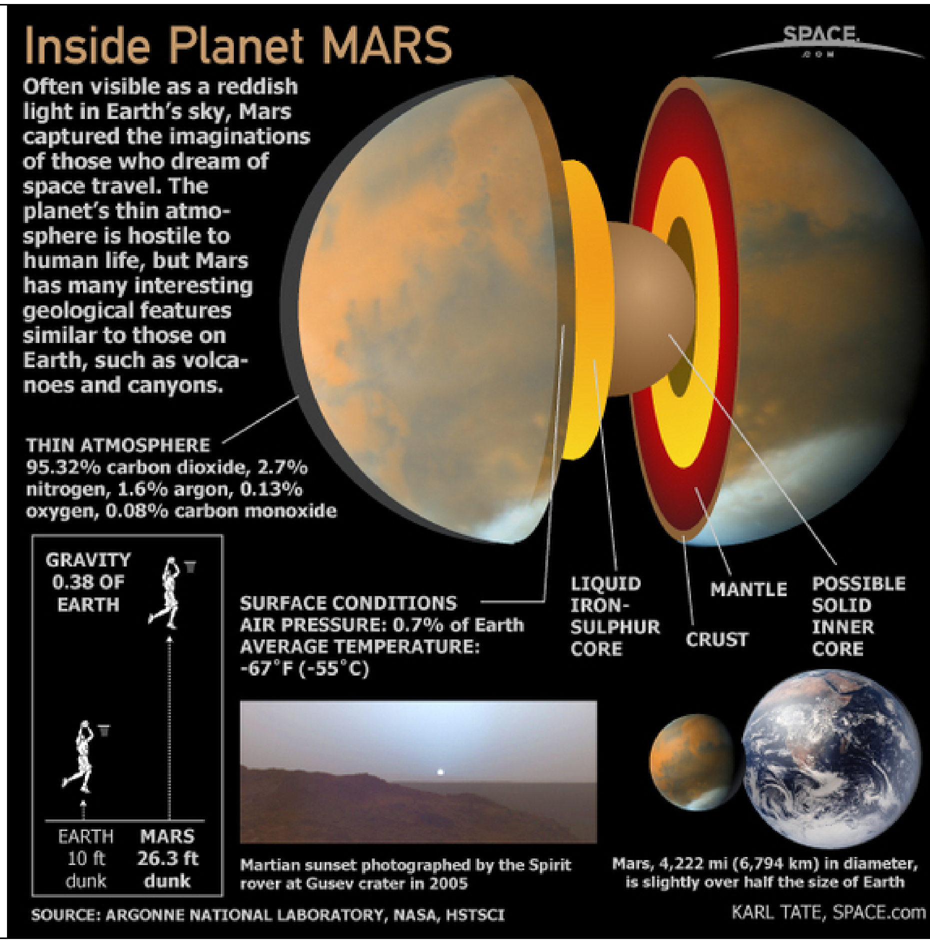
	Messenger became the first spacecraft to orbit Mercury in 2011.

Venus ♀ The Roman goddess of love Venus is often referred to as Earth's sister planet. It is of a similar size, mass and composition but there the similarities end.	
♀	**Symbol represents:** hand mirror
Diameter	7520 miles (12,092 km)
Temperature	Ranges from 900°F +/- 50°F (about 500°C +/- 32°C) at the surface. The atmosphere traps the small amount of energy from the sun that does reach the surface along with the heat the planet itself releases. This greenhouse effect has made the surface and lower atmosphere of Venus one of the hottest places in the solar system!
Average distance from the sun	67,240,000 miles (108,200,000 km)
Orbiting the sun	225 days
Distance from Earth	38 million kilometers at closet distance
Composition	Atmosphere: Mostly carbon dioxide. Thick clouds of sulfuric acid completely cover the planet.
Moons	0

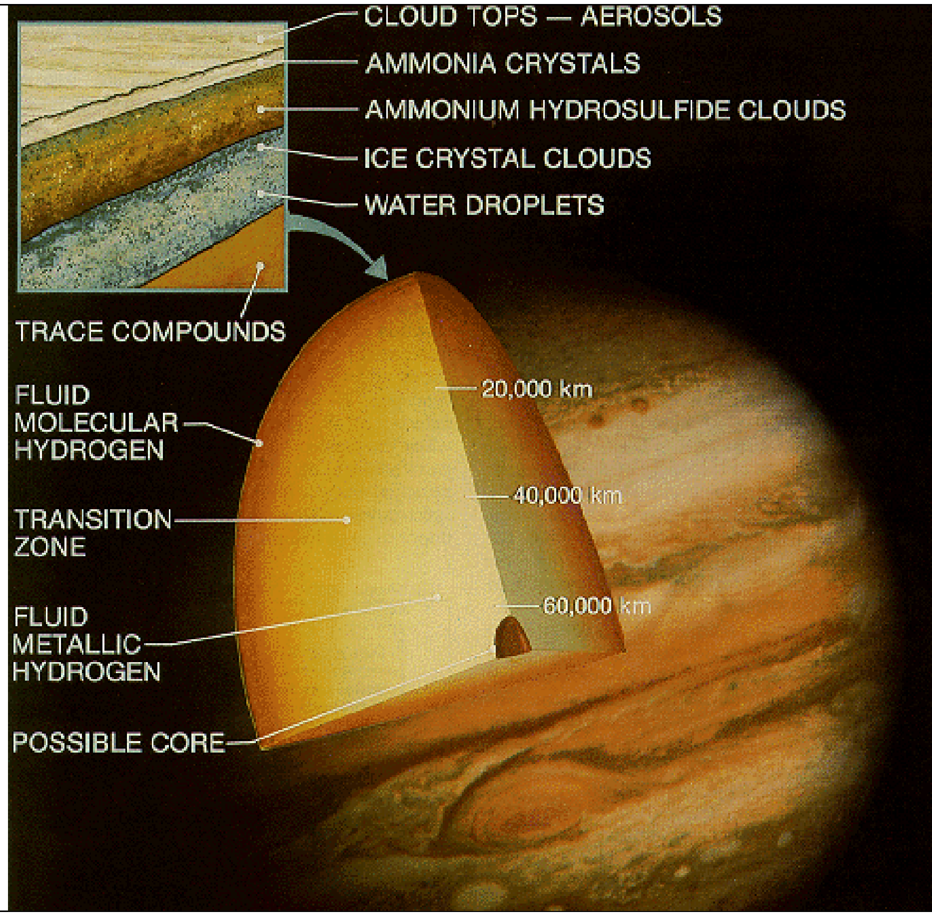
Exploration	Numerous unmanned missions have been launched to Venus, including 10 successful landings and 7 orbiters.

<table>
<tr><td>Mars
♂

The Roman god of war

The red planet</td><td>
</td></tr>
<tr><td>♂</td><td>Symbol represents: Shield and spear</td></tr>
<tr><td>Diameter</td><td>4223 miles (6796 km)</td></tr>
<tr><td>Temperature</td><td>-140 to 20°C (-220 to 60°F)</td></tr>
<tr><td>Average distance from the sun</td><td>141.6 million miles (228 million km)</td></tr>
<tr><td>Orbiting the sun</td><td>687 days</td></tr>
<tr><td>Distance from the Earth</td><td>Varies from approximately 40 million to 60 million kilometers at its closest distance</td></tr>
<tr><td>Mass</td><td>6.41693×10^{23} kilograms or .107 of earth</td></tr>
<tr><td>Composition</td><td>Soil: silicon 18 – 25%, iron 12–15%, oxygen 40–45%, potassium 8%, calcium 3-5%, magnesium 3-6%, sulphur 2-5%, aluminum 2-5%, cesium 0.1-0.5%</td><td>Atmosphere: mainly carbon dioxide</td></tr>
<tr><td>Moons</td><td>2 (Phobos and Deimos)</td></tr>
</table>

Exploration	21 successful missions have been sent to explore Mars, including 3 landers and 4 rovers.

Jupiter ♃ The Roman king of the gods		
♃	**Symbol represents:** the letter *zeta* or *Z* for Zeus, the Greek god analogous to Jupiter	
Diameter	85,788 miles (138062 km) in diameter (the largest planet) - more than 11 Earths could line up across it	
Temperature	-163° C to -121° C	
Average distance from the sun	Approximately 466 million miles (750 million km)	
Orbiting the sun	12 Earth years	
Distance from the Earth	391 million miles (629 million km) at closet distance	
Mass	Jupiter's mass is 2.5 times that of all the other planets in our Solar System combined	
Composition	mostly hydrogen and helium	
Known Moons	at least 66	The most important ones: Io, Europa, Ganymede, Callisto
Exploration	Seven spacecraft have performed flyby missions, and one (Galileo) orbited Jupiter for over 7 years. The Juno mission is scheduled to reach orbit in 2016.	

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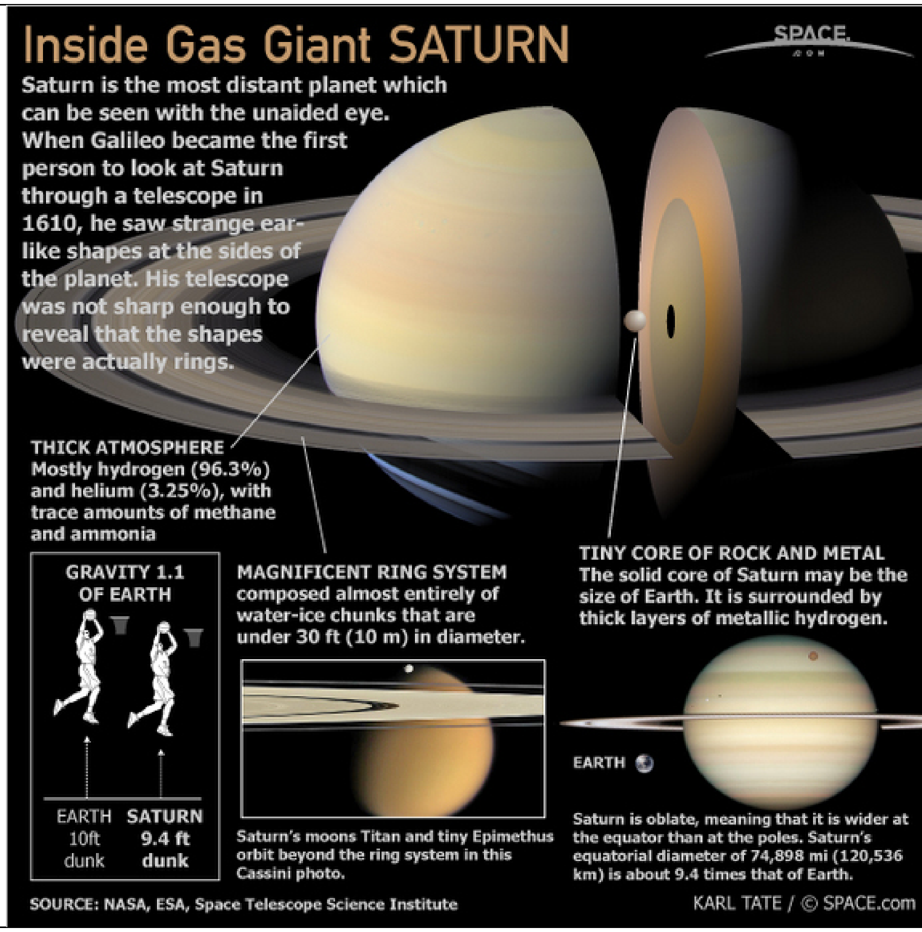
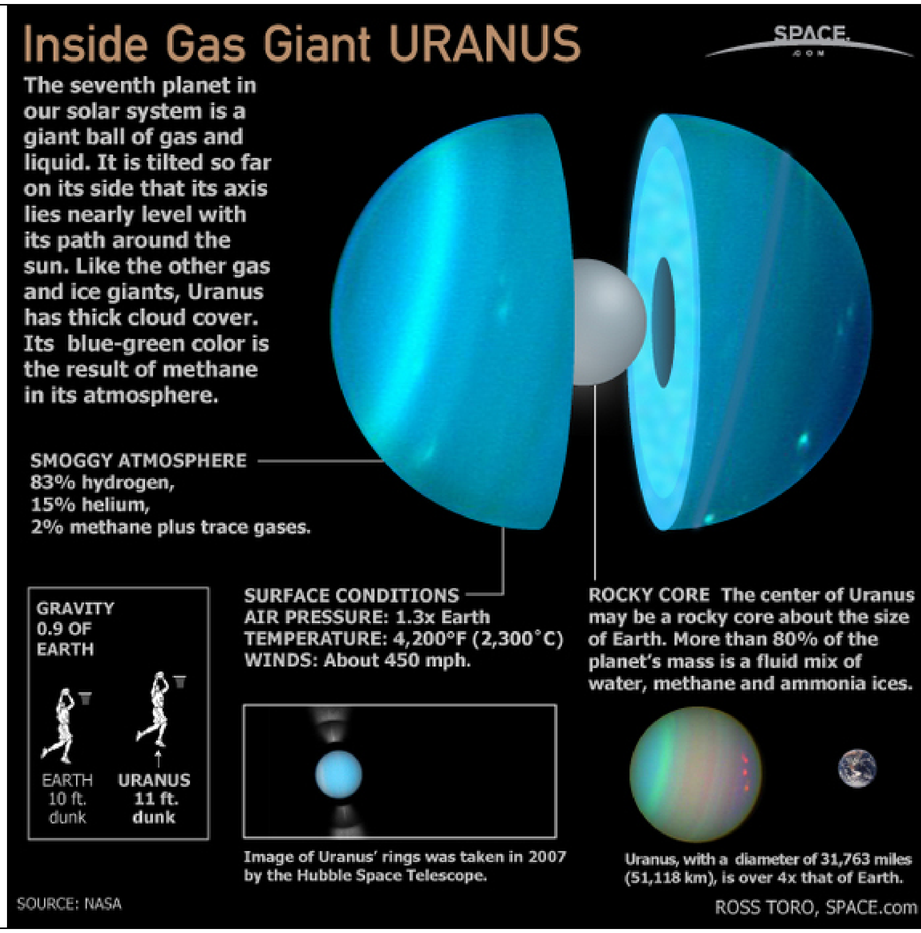
Saturn ♄	
♄	**Symbol represents:** Sickle or scythe
Diameter	120,660 km. It is about 10 times larger than our Earth
Temperature	-178°C
Average distance from the sun	67,240,000 miles (108,200,000 km)
Orbiting the sun	29.5 Earth years
Distance from the Earth	740 million miles (1190.4 million km) at closest distance
Composition	Mostly hydrogen and helium
Known Moons	62
Exploration	From 1973 to 2004 United States has had four space missions to Saturn: three fly-bys (Pioneer, Voyager I and II) and one orbiter (Cassini).

http://www.windows2universe.org/saturn/space_missions.html

Uranus

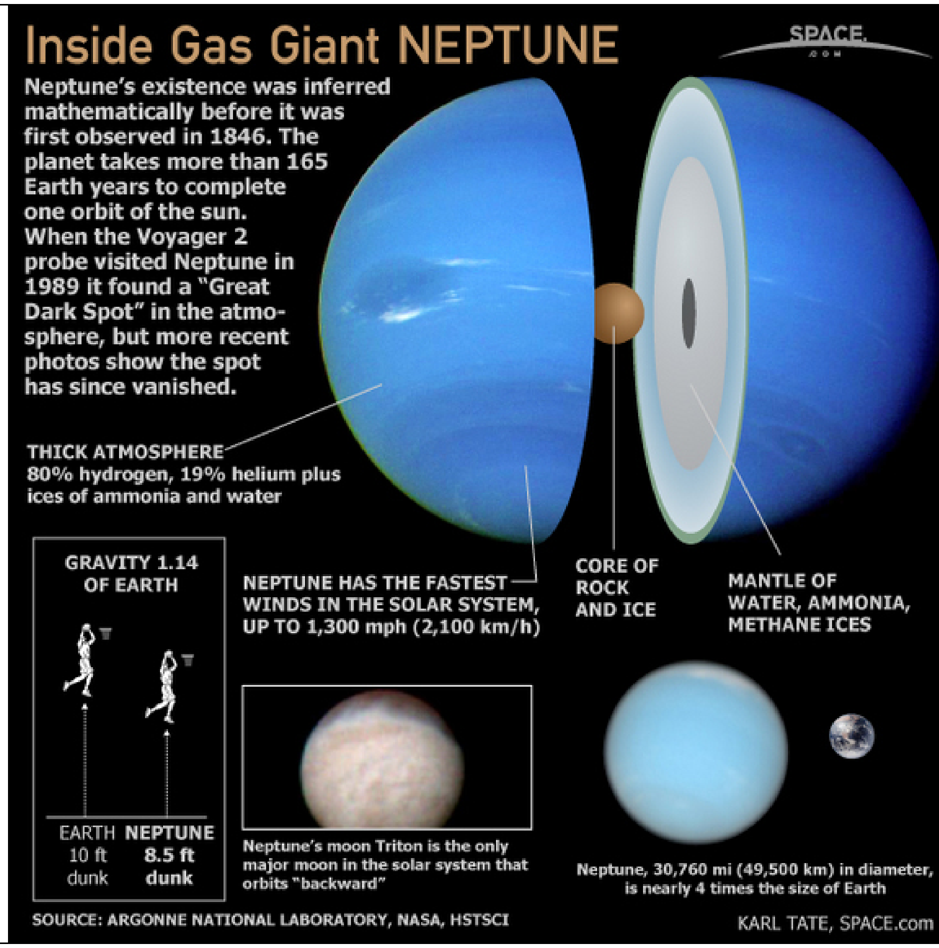
⛢



⛢	**Symbol represents:** Platinum ; or, a combination of the symbols for Sun and Mars
Diameter	Approximately 32,000 miles (51,000 km)
Temperature	As low as -224°C
Average distance from the sun	1.78 billion miles (2.88 billion km)
Orbiting the sun	84.3 Earth years
Distance from the Earth	1.60 billion miles (2.57 billion km) at closest distance
Composition	Mostly hydrogen and helium, with significant amounts of methane in the upper atmosphere
Known Moons	27; the more famous ones: Titania, Ariel, Miranda, Oberon
Exploration	1986, Voyager II. It took over 9 years for the space craft to reach Uranus.

Neptune

♆



♆	**Symbol represents:** trident
Diameter	Approximately 31,000 miles (49,500 km)
Temperature	As low as -218°C
Average distance from the sun	2.8 billion miles (4.45 billion km)
Orbiting the sun	About 165 years
Distance from the Earth	About 2.7 billion miles (4.4 billion km)
Composition	Mostly hydrogen and helium, with significant amounts of methane in the upper atmosphere
Known Moons	13
Exploration	1989, Voyager II

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Canyon Diablo Meteorite

Earth has been impacted by rocks from space throughout its 4.5 billion year history. Unlike the heavily cratered Moon, however, the results of those impacts can be difficult to see; wind, weather and the varied surface of our planet have concealed or erased much of the evidence. Nevertheless, meteorites (the portion of the meteor that survives the impact) have been found on every continent of Earth. When meteorites are found, it is often difficult to piece together the story of their arrival. The Canyon Diablo Meteorite is different – the crater made by this object's arrival can be visited today.

About 49,000 years ago, a meteor about 150 feet across, and traveling at a speed of 26,000 miles an hour, struck Earth in what is now northern Arizona. The impact released energy equivalent to 2.5 million tons of TNT, or about 150 Hiroshima-sized atomic bombs.

The object was mostly iron and nickel, and weighed an estimated 300,000 tons. Most of the meteorite was melted by the force of the impact, but fragments were scattered over a wide area. The crater formed by this impact, now called Barringer Crater (or Meteor Crater), is ¾ of a mile across and was originally 750 feet deep. At the time of the impact (during the last ice age), this part of North America was heavily forested, but in the centuries since, the climate changed to a dry desert, which limited erosion and helped preserve the crater's features.

Meteorites from this impact are named for nearby Canyon Diablo, which lies a few miles west of the crater. The meteorites have been known and collected from this site since the mid-19th century. Other notable fragments are on display in Chicago, Paris, Philadelphia, and Los

Angeles, as well as the largest known fragment, called the Holsinger Meteorite, weighing 639 kg (1409 lb), on display at the crater's visitor center.

This specimen (and the other 42 Canyon Diablo meteorites in the Academy's collection) was found in 1891. It weighs approximately 100 kg (221 lb). Its surface clearly shows the result of the melting and cooling that took place upon impact.

The meteorite is classified as a coarse octahedrite, composed mostly of iron with approximately 7% nickel and traces of other metals. A magnet held near this specimen will clearly demonstrate its high iron content. Interestingly, most known meteorites are stony rather than metallic; only about 6% of meteorites are metal, or blends of rock and metal.

The Canyon Diablo meteorites have been age-dated to 4.55 billion years, meaning that this object dates from the earliest days of the solar system, a time when Earth and the other planets were still forming. Rocks of this age are unknown on Earth, as the effects of plate tectonics and erosion have continually modified the surface of our planet. When you touch this meteorite, you're touching one of the oldest rocks known on Earth.

http://www.barringercrater.com/about/history_1.php
http://www.lpi.usra.edu/meteor/metbull.php?code=5257
http://www.newark.osu.edu/facultystaff/personal/jstjohn/Documents/Rocks-from-Outer-Space/Octahedrite.htm

<u>Foucault Pendulum</u>

A pendulum is a weight suspended from a fixed point which, when pulled back and released, swings down by force of gravity. Once past the low point of its arc it continues to move up and out because of its inertia. The back-and-forth motion of a pendulum can be visualized if you think about the motion of a grandfather clock. Inertia means that bodies in motion will stay in motion; bodies at rest will stay at rest - unless acted on by an outside force.

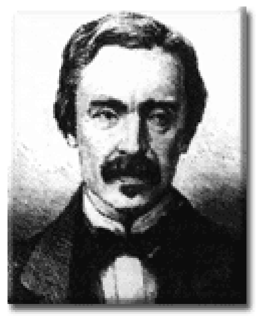
The Academy's pendulum is not a clock, compass or perpetual motion machine. It is a Foucault pendulum*. It proves that the Earth rotates on its axis.* As the force of gravity keeps the bob swinging back and forth, our planet's spin causes a tiny "force" that changes the direction of the pendulum's path a little bit with each swing. If Earth didn't rotate, the pendulum would swing across exactly the same spot all day. The change in direction of the pendulum's path is called precession.

The first demonstrated Foucault pendulum was built by Jean-Bernard-Leon Foucault (pronounced "foo-KOH"), in 1851, in the Meridian Room of the Paris Observatory. A few weeks later he installed a more famous pendulum in the Panthéon in Paris. This pendulum was 67 meters (219 feet) long, and the bob weighed 28 kilograms (61.7 pounds.)

Before 1851 it was widely accepted that the Earth rotated on its axis. The following observations were consistent with this hypothesis:

- Sunrise and sunset
- The apparent motion of the stars at night
- Measured polar flattening and equatorial bulge
- Cyclonic weather systems and oceanic currents

Foucault's pendulum, however, was the first satisfactory demonstration of the Earth's rotation on its axis using laboratory apparatus rather than astronomical observations.



Jean-Bernard-Leon
Foucault

Design and Operation of the Academy's Foucault Pendulum

The original pendulum was installed in the old Academy in 1951, and was very popular. It was damaged in the fire that destroyed the planets in space hall, and is now in storage.

Design

The pendulum consists of a heavy weight, called a bob, hung with aircraft control wire anchored to the ceiling. The cable is mounted in a manner that permits it to rotate independently from the ceiling. The bob is a hollow brass ball 16 inches in diameter and weighs 238 pounds. In the old Academy the pendulum pit was recessed into the floor, but the new pendulum pit is not recessed because a pendulum was not in the original plans for the new Academy. When it was decided to have a pendulum the pit was designed to use the already established floor.

The pendulum is not a perpetual motion machine! If left alone, friction from air resistance will cause the pendulum to slow down and eventually stop. A decline in the swing would be noticeable within two or three hours, although it would take much longer for the pendulum to come close to stopping. The bob is heavy compared to the wire; this minimizes but does not eliminate the effect of air resistance. An electromagnet at the top of the cable keeps the pendulum swinging.

The pendulum is so heavy that the ground waves of an earthquake would have little or no impact on the pendulum's swing.

Operation

At the top of the wire there is an iron collar. When the pendulum wire is perpendicular to the floor, it triggers electricity to flow through an electromagnet, activating the magnet. The magnet then pulls the collar in the direction of the swing, giving it a slight "pull" to keep the pendulum from slowing down. When the collar hits the magnet the electricity turns off, deactivating the magnet. The pendulum then swings in the other direction, free from the influence of the magnet. When the wire becomes perpendicular to the floor the magnet is again activated, pulling the iron collar in the other direction.

The period of the pendulum is the time that it takes for the bob to make one cycle – in other words, the time it takes to leave and return to the same position. Longer cable lengths give longer periods.

On Wednesday October 15, 2008, the period was measured at 6.4 seconds. From this, the length of the cable in feet was calculated from the following formula:

$L \approx gT2/4\pi 2$ = 33.4 feet (10.2 meters) = 33 feet 5 inches; $L \approx$ L approximately equals

g = acceleration due to gravity, 32.17 ft / sec2
T = period, seconds
π = 3.142
L = cable length, feet

The formula is accurate only if the pendulum swings through a small angle.

To start the pendulum, a staff member holds the cable and pulls the bob back to the desired position of maximum swing. The cable is held until the cable and bob are perfectly steady. Then the staff person lets it go.

There are 60 pegs, and 60 spaces between them. One complete precession (360°) takes 39.2 hours (2350 minutes.) Dividing 2350 minutes by 60 gives 39.2 minutes (39 minutes 10 seconds) between peg knockdowns. This is a theoretical average; actual times can vary.
A staff member resets the pegs every morning, at about 9:30.

What the Pendulum Demonstrates

The plane (direction of swing) of the pendulum's swing appears to turn "precess" clockwise above the floor. The Earth's rotation causes the precession. We do not feel the motion of rotation because the forces resulting from the motion are very small.
At either the North or South Poles (and *only* at the poles) the plane of the pendulum's swing is fixed with respect to the stars. At the North Pole the plane of the pendulum's swing precesses

clockwise with respect to the ground, taking one sidereal day (see glossary) to complete a rotation. At the South Pole the plane of oscillation precesses counterclockwise.

At the equator the pendulum doesn't precess at all – the plane of oscillation remains fixed relative to Earth. At other latitudes the plane of oscillation precesses relative to Earth but slower than that at the poles.

In San Francisco one complete clockwise precession takes 39.2 hours. This can be calculated:

- Time, hours = (sidereal day, hours) / sin(latitude of San Francisco)
- One sidereal day = 23.93 hours
- Time = 23.93 / sin(37.77 degrees) = 39.2 hours in San Francisco

So, at the North Pole (latitude 90 degrees) it takes 23.93 hours; at the equator (latitude 0) it takes forever – the plane of the pendulum's swing does not precess at all.

The Coriolis Effect (aka Coriolis Force)

The Coriolis effect can arise in any situation involving rotation. Imagine that you're in an airplane at the North Pole. You take off heading due south. If Earth was not rotating you would maintain a path along a fixed longitude. But the Earth *is* turning under you, from west to east. Your path in the airplane will veer toward the right (toward the west) as seen from the ground.

Another way to think about this is to be in an airplane at the equator. You take off heading due north. Again, if Earth was not rotating you would maintain a path along a fixed longitude. But the Earth *is* turning under you. At the equator the ground velocity from west to east is about 1,040 miles per hour, *and this is also your velocity from west to east*. As you head north *your* west to east velocity is still 1,040 miles per hour but the west to east velocity of the ground under you is continually decreasing. You veer to the right (toward the east) as seen from the ground.

This effect causes hurricanes (north of the equator) to spin counterclockwise. As winds veer to the right the low pressure at the center tends to pull them inward, resulting in the counterclockwise rotation. Major ocean currents are also affected.

South of the equator the effect is reversed. The airplane heading north from the South Pole would be seen veering to the west; heading south from the equator would be seen veering to the east. Cyclonic rotation is clockwise.

Tornadoes, like hurricanes, are cyclonic systems, but the distance across their funnel clouds is too small to have their rotation determined by the Coriolis effect. They can spin clockwise or counterclockwise in either hemisphere. However, the rotation of a tornado is determined by the rotation of the thunderstorm that spawns it. Some thunderstorms are big enough to have their rotation determined by the Coriolis effect. Thus most – but not all – tornadoes in the northern hemisphere rotate counterclockwise. One clockwise – spinning tornado struck near Sunnyvale in 1998.

"Tropical cyclone" is a general term referring to hurricanes and typhoons. Hurricanes are cyclones in the Atlantic Ocean; typhoons are cyclones in the Pacific. These systems normally develop in the tropics, but rarely within 5o latitude of the equator. The Coriolis effect is too weak near the equator to give rise to cyclones.

Other examples of cyclonic systems are dust devils and waterspouts. Waterspouts are tornadoes over water.

Cyclonic systems are also seen on other planets. A famous example is the Great Red Spot on Jupiter, an enormous system that has lasted for hundreds of years. Cyclonic systems have also been detected at Saturn's poles.

Some myths or mistaken ideas

It is incorrect to say that "The Earth is rotating under the pendulum." This is correct only at the North and South Poles.

It is incorrect to say that the plane of oscillation of a pendulum remains fixed with respect to the stars. This is correct only at the Poles. (For example, think about a pendulum at the equator. As the Earth rotates, stars rise or fall in the direction of the pendulum's swing.)

The direction of water rotation in draining sinks is *not* determined by the rotation of the Earth. The Coriolis effect is tiny at this small scale and is overridden by other effects.

Additional resources

http://www.calacademy.org/products/pendulum/
http://www.physclips.unsw.edu.au/jw/foucault_pendulum.html
http://helix.gatech.edu/Classes/ME2202/2000S3/Projects/Swarner/index.html
http://geosci.uchicago.edu/~nnn/LAB/DEMOS/coriolis.html
http://www.dvandom.com/coriolis/
http://www.spc.noaa.gov/faq/tornado/#The%20Basics

Pocket Solar System

GRADE LEVEL	3^{rd} - 8^{th}
SUBJECTS	Earth Sciences, Investigation & Experimentation
DURATION	Preparation: 5 minutes Activity: 10 minutes
SETTING	Classroom

Abstract
Students will build a quick model of the solar system by folding a piece of register tape to illustrate the relative distances between the orbits of the planets. Images in textbooks often depict the planets squeezed together, but this model shows how far apart they are, especially beyond Mars.
Lesson courtesy of our friends from the Astronomical Society of the Pacific

Objectives
By folding a piece of register tape repeatedly, students will visualize the relative distances between the orbits of the planets.

Materials
- strips of register tape (one meter per student)
- round stickers (5 large & 5 small per student)
- pencils

Activity

Preparation
If you are doing this activity with a large group, you can pre-cut 1 m strips of register tape and divide out groups of stickers for each participant. If you wish, practice the steps a few times so you don't have to refer to your notes.

Introduction
For any of these scale model activities, it is useful to start by exploring the notion of models. Referring to playthings, such as dolls or toy cars, can be a useful reference for talking about scale models.

Pull out a folded, completed sample of the model from your pocket. Point out that the planets never appear in a straight line like this in order out from the Sun, but this is just a reminder of the radius of the orbits. The planets would be found somewhere along a circle this far from the Sun. If you have a board with a thumbtack, you can tack it to the board at the Sun and show or draw out the orbits.

Procedure

Now have the participants create their own Pocket Solar System models. Lead them through the following steps:

1. **Sun & Pluto (on the edges):**
   Make a mark on each end of the tape, one large and one small, right at the edge. Label the large one Sun and the small one Pluto. Even though Pluto has been reclassified as a dwarf planet it serves as a useful reference point here. We can use it as the first example of such a dwarf planet ever found, just as we'll use Ceres to represent the asteroid belt later on.
2. **Uranus (1/2):**
   Fold the tape in half, crease it, unfold and lay flat. Place a large sticker at the halfway point. You can ask for guesses as to which of the planets might be at this halfway point. Label the sticker Uranus.
3. **Saturn (1/4) and Neptune (3/4):**
   Fold the tape back in half, then in half again. If there are mixed ages, give those with some knowledge of fractions the opportunity to show off by asking "What is half of a half?" Unfold and lay flat. Place large stickers at the quarter mark and 3/4 marks and label as Saturn (closer to the Sun) and Neptune (closer to Pluto).
4. **Jupiter (1/8):**
   Fold back into quarters, then in half one more time. This will give you eighths. Unfold and lay flat again. Place a large sticker for Jupiter at the 1/8 mark (between the Sun and Saturn), and label.
5. **Asteroid Belt (1/16):**
   No need to fold the whole thing up again. If you take a look, you've got the 4 gas giants and Pluto all on there in the outer solar system. For the remaining terrestrial planets, you'll only need 1/2 of the first 1/8th! That's the inner 1/16th of your meter. Fold the Sun out to meet Jupiter to mark the 1/16th spot. A planet does not go here, but you should label this Ceres to represent the Asteroid Belt.
6. **Earth (inside 1/32), Mars (outside 1/32) :**
   At this point, things start getting a little crowded and folding is tough to get precise distances, so fold the remaining 1/16th in half and crease at the 1/32nd spot. Place a small sticker for the Earth just inside this fold (between the Sun and Ceres) and a small sticker for Mars just outside the fold (closer to Ceres and the Asteroid Belt) and label them.
7. **Mercury & Venus (between Earth & Sun):**
   Place small stickers for Mercury and then Venus, between the Earth and Sun, pretty much dividing the space into thirds and label them as Mercury closest to the Sun and Venus closest to the Earth.

Wrap-Up

At the end of the discussion, be sure to have everyone put their names on their tapes and fold them up to put it in their pockets. But before you put them away, here are some questions you might ask to get participants thinking about insights they can get from building this model.

1. Are there any surprises? Look how empty the outer solar system is: there is a reason they call it space! And how crowded the inner solar system is (relatively speaking).
2. Do you know anything about the physical properties of the ones that are spread out versus the ones that are crowded in close to the Sun? All the inner ones are small and rocky and the outer ones are gassy giants (except small, icy Pluto).
3. Given this spacing, why do you think little, rocky Venus can outshine giant Jupiter in the night sky? Both are covered with highly reflective clouds, and although it is much smaller, Venus is also much, much closer.
4. Does anyone know where the Eris, the largest dwarf planet would go on this model? At 97 A.U., it would more than double the size of the model. Pluto is on average 40 A.U. [A.U. stands for Astronomical Unit, roughly the mean distance from the Earth to the Sun. 1 AU = 149,597,870.691 kilometers, or about 93 million miles.]
5. On this scale (1 m = 40 A.U.) where would the nearest star be? After some guesses you could bring out your pocket calculator to use in getting how far away the star would be. This allows you to talk about how far is a light year and do the calculations to find that the next nearest star is about 7 km (4.2 miles) away. They could then take out a local map to see what is that far away from where the presentation is happening. [Calculations: A light year, the distance light travels in one year, is about 63,240 A.U. (about 9,460,000,000,000 km). The nearest star is Proxima Centauri (visible from the Southern Hemisphere), at 4.2 light years. So, 4.2 l.y. x 63,240 A.U./l.y. x 1 m/ 40 A.U. = 6640.2 m = about 7 km.]

Resources

Gallagher, Amie. Raritan Valley Community College.
Astronomical Society of the Pacific, www.astrosociety.org/education.html

California Content Standards

Grade Five

Earth Sciences

5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

Correlated California New Science Standards

Middle School

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system

Worlds in Comparison

GRADE LEVEL	4^{th} - 8^{th}
SUBJECTS	Earth Sciences, Investigation & Experimentation
DURATION	Preparation: 5 minutes Activity: 20 minutes
SETTING	Classroom

Abstract
This activity allows participants to develop an understanding of the relative sizes (volumes) of the planets in the solar system by dividing a big ball of playdough to see how the planets vary in size.

Lesson courtesy of our friends from the Astronomical Society of the Pacific

Objectives
By dividing a ball of playdough into spheres to scale, students will visualize the relative volumes of the eight planets of our solar system in addition to the dwarf planet Pluto

Materials
- playdough (three pounds per group)
- plastic knife (one per group)
- wax paper (one sheet per group)
- student worksheets (one set per group)

Vocabulary
- **planet:** a large celestial body, smaller than a star but larger than an asteroid, that does not produce its own light but is illuminated by light from the star around which it revolves.
- **volume:** the amount of three-dimensional space occupied by an object.

Activity

Preparation
This activity works best if the worksheets with the planet names are placed side-by side on a table, and are arranged to match the order from the Sun. In front of these sheets, place the instruction sheet, the playdough, and plastic knife on the breadboard (or equivalent). Be sure there is enough room in front of the table for the group to work together. It is crucial to have the indicated amount of playdough for each group. If there is less than three pounds, the Pluto piece will be too small to see! We recommend three pounds each and urge you to try the activity for yourself before leading it.

Introduction

For any of these scale model activities, it is useful to start by exploring the notion of models. Referring to playthings, such as dolls or toy cars, can be a useful reference for talking about scale models.

This activity is designed as a self-guided station activity. Nevertheless, if you choose to do so, it can also be a facilitated activity from the beginning. If you facilitate this activity from the start, begin by asking the participants which planet they think is the largest. For whatever planet they say is the largest (it will most likely be Jupiter), ask them the following question: If we could combine all the planets together into a big ball, what fraction of that ball would the largest planet be? Might it be 1/9 or 1/5, for example? Which is the smallest? Some may say Pluto, even though it is no longer defined as a major planet, but is a dwarf planet. For our purposes, that is fine. We've kept it in this activity and it will be dramatically demonstrated just how much smaller it is than the others. End the introduction by telling them they will get a better idea of these relative sizes or volumes after completing this activity.

Note:
If people will be using previously used playdough of various colors, you can reassure participants that mixing colors is fine (after all, many planets are multicolored!).

Procedure

Participants start by reading the instructions handout, but they should get into working with the playdough as quickly as possible. They should follow the instructions as to how to divide up their playdough, placing the parts in the proper planet boxes. Each time the playdough is divided up and parts are combined to make a planet, be sure participants roll the combined parts around in their hands until the planet has a ball shape.

Wrap-Up

Start by asking the group about some of the discoveries they made regarding the sizes of the planets. Were there any surprises? Ultimately direct the discussion so that they realize the smaller planets (except the dwarf planet Pluto) are the inner planets, while the larger planets are the outer planets. You may also want to note that more than 96% of the combined volume of the planets is in Jupiter and Saturn (approximately 60% in Jupiter and 36% in Saturn). Those giant planets really ARE giants.

References

Schatz, Dennis. Family ASTRO Program. Pacific Science Center.
Astronomical Society of the Pacific, www.astrosociety.org/education.html

California Content Standards

Grade Five

Earth Sciences

5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

Correlated California New Science Standards

Middle School

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system

Instruction Sheet

Start with a big 3-pound ball of playdough, which represents the volume of all the planets combined.

1. Divide the Entire Ball of Playdough into 10 Equal Parts

You may find it easiest to start by rolling the ball into one big hot dog shape.

- Combine 6 parts together and put them into the Jupiter box.
- Similarly combine 3 parts and put them into the Saturn box.

2. Cut the Remaining Part into 10 Equal Parts

- Take 5 parts and combine them with the ball in the Saturn box.
- Combine 2 parts to put into the Neptune box.
- Combine 2 parts to put into the Uranus box.

3. Cut the Remaining Part into 4 Equal Parts

- Take 3 parts and combine them with the ball in the Saturn box.

4. Cut the Remaining Part into 10 Equal Parts

- Put 2 parts into the Earth box.
- Put 2 parts into the Venus box.
- Take 4 parts and combine them with the ball in the Uranus box.

5. Combine the Remaining 2 Parts and Cut into 10 Equal Parts

- Put 1 part into the Mars box.
- Take 4 parts and combine them with the ball in the Neptune box.
- Take 4 parts and combine them with the ball in the Uranus box.

6. Cut the Remaining Part into 10 Equal Parts

- Put 7 parts into the Mercury box.
- Take 2 parts and combine them with the ball in the Uranus box.

7. Cut the Remaining Part into 10 Equal Parts

- Take 9 parts and combine them with the ball in the Uranus box.
- Put 1 part into the Pluto box.

And Now...

Now that you have divided the playdough to represent the planets by volume, roll the pieces in each planet's box into balls to best represent the shapes of the planets

By Dennis Schatz (Pacific Science Center)

Mercury

Venus

Earth

Mars

Jupiter

Saturn

Uranus

Neptune

Pluto

Kinesthetic Astronomy: Set Up

GRADE LEVEL	4^{th}-5^{th}
SUBJECTS	Earth Sciences, Astronomy
DURATION	Preparation: 20 minutes
SETTING	Classroom

Construction of signs:

Print the 12 Zodiac signs in B&W or color. It is best to laminate for repeated use. If desired, use a 3-hole punch to put holes along the top edge of each sign. Weave a loop of string (36 inches in length) through the holes. This will assist you in hanging them up so they are easier to see in the learning environment.

How to set up the kinesthetic circle

1. Determine where you will set up the Kinesthetic Circle with the "Sun" at the center. Choose the direction toward which students will be "tilting toward Polaris" (see diagram on the next page).

2. Find Earth's position on 21 June, the summer solstice. This is the place in the circle where being tilting toward Polaris results in your upper body leaning directly towards the Sun. Place the "Summer Solstice" sign on the ground as in the Zodiac Diagram.

3. Circle the Sun in a *counterclockwise* direction for ¼ of an orbit. Place the "Fall Equinox" sign.

4. Place the "Winter Solstice" and "Spring Equinox" signs accordingly.

5. Return to the Summer Solstice position. Face away from the Sun – midnight on the Summer Solstice. Place Sagittarius slightly to your left and Scorpio slightly to your right.

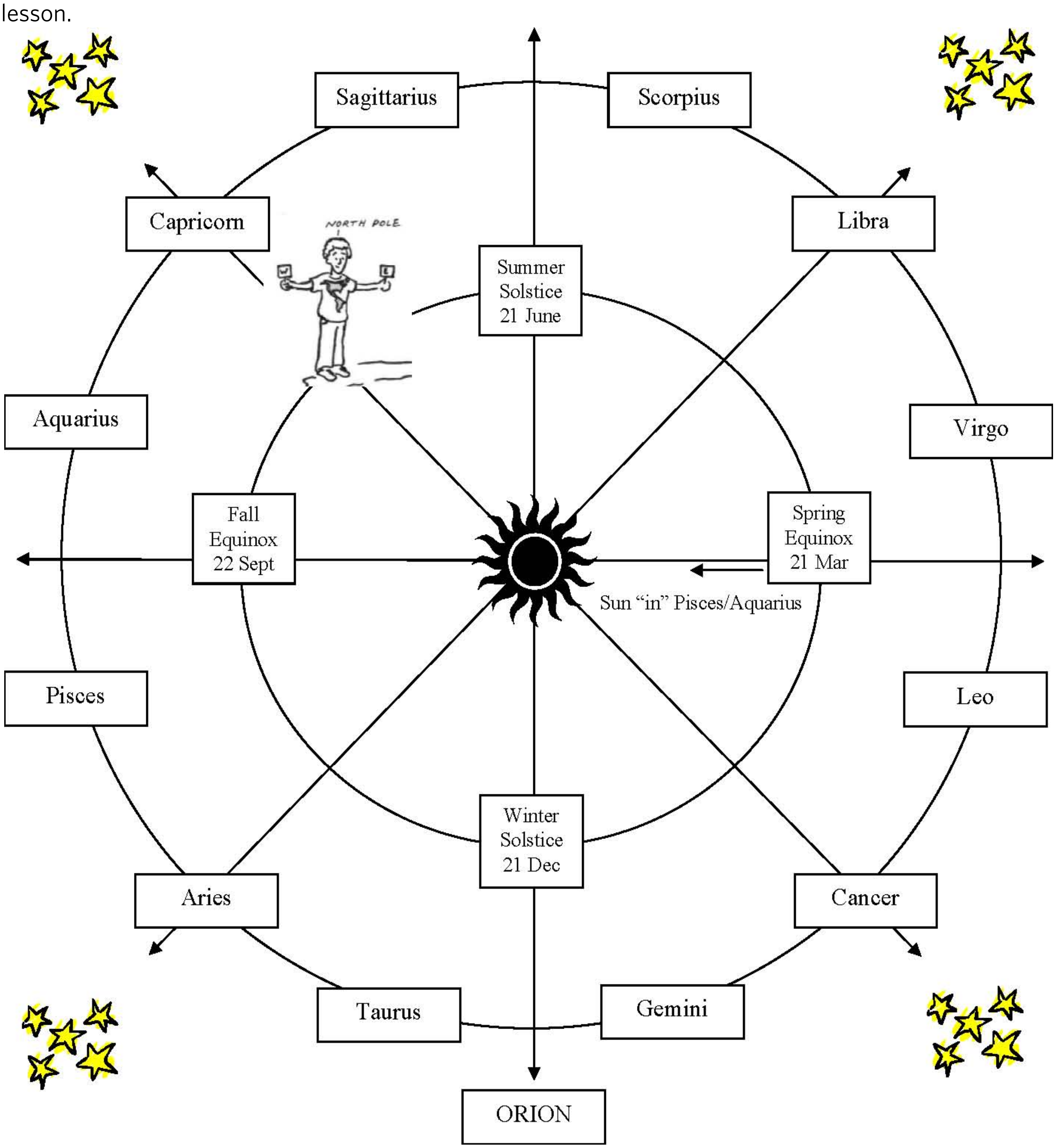
6. Place the remaining Zodiac signs as shown. Hanging the signs from chairs or taping them to the wall at the height of the balloon makes them more readable to students in the Kinesthetic Circle.

7. Mark earth's orbit with 12 pieces of tape (one for each month). This will guide the students in where to stand.

8. If you are planning on doing the Mars Opposition Dance, make another orbit outside of Earth's orbit with 24 pieces of tape to mark the two earth years it takes Mars to orbit the sun.

THE ZODIAC DIAGRAM

The diagram below depicts the modern order of the Zodiacal constellations relative to the Sun (not to scale). It also indicates Earth's orbital locations at the two solstices and two equinoxes. The boy represents Earth on the Kinesthetic Circle (as defined in the "Sky Time" lesson). If you know how to use a planisphere, you can confirm the positions of the constellations of the Zodiac along the ecliptic. Note also the effects of precession. When western astrological signs were first assigned, the Sun was "in" Aries at the Spring equinox. These days the Sun is between Pisces and Aquarius. Orion (below the ecliptic between Taurus and Gemini) is a familiar constellation for optional use in the "Sky Time" lesson.



Morrow & Zawaski (Aug 2004)
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WINTER

SOLSTICE

21 December

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SPRING

EQUINOX

21 March

Morrow & Zawaski (Aug 2004)
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SUMMER

SOLSTICE

21 June

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FALL

EQUINOX

21 September

Morrow & Zawaski (Aug 2004)
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SAGGITARIUS

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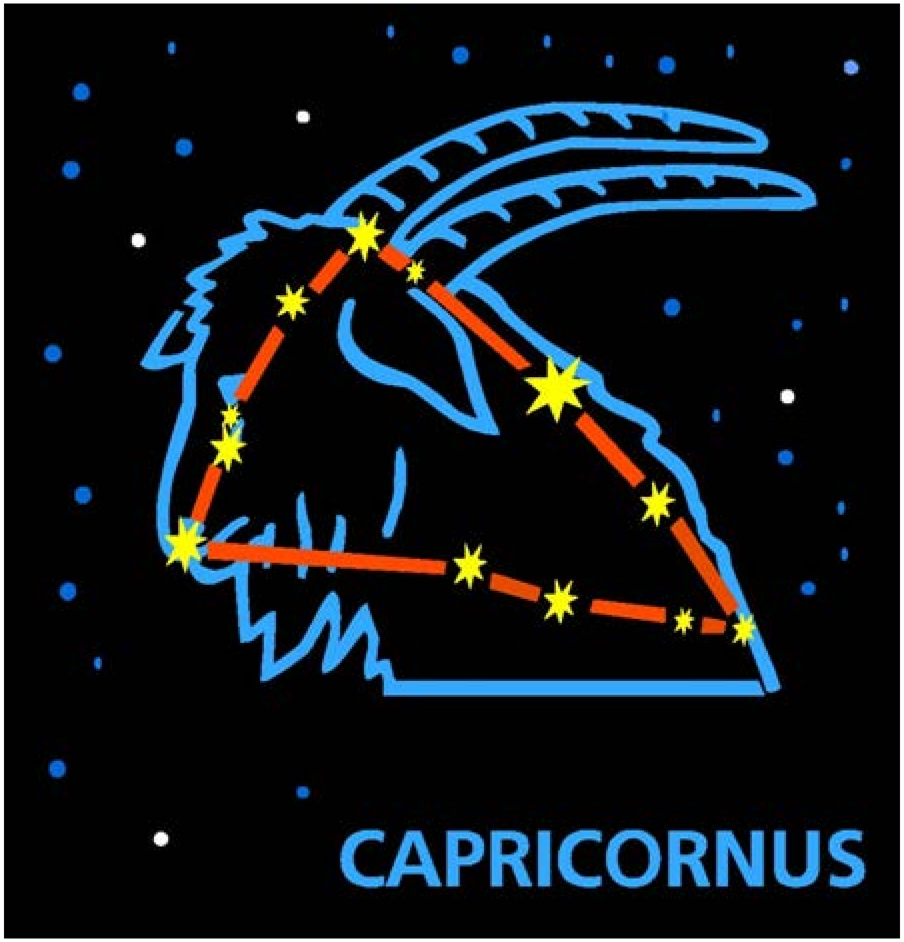
CAPRICORNUS



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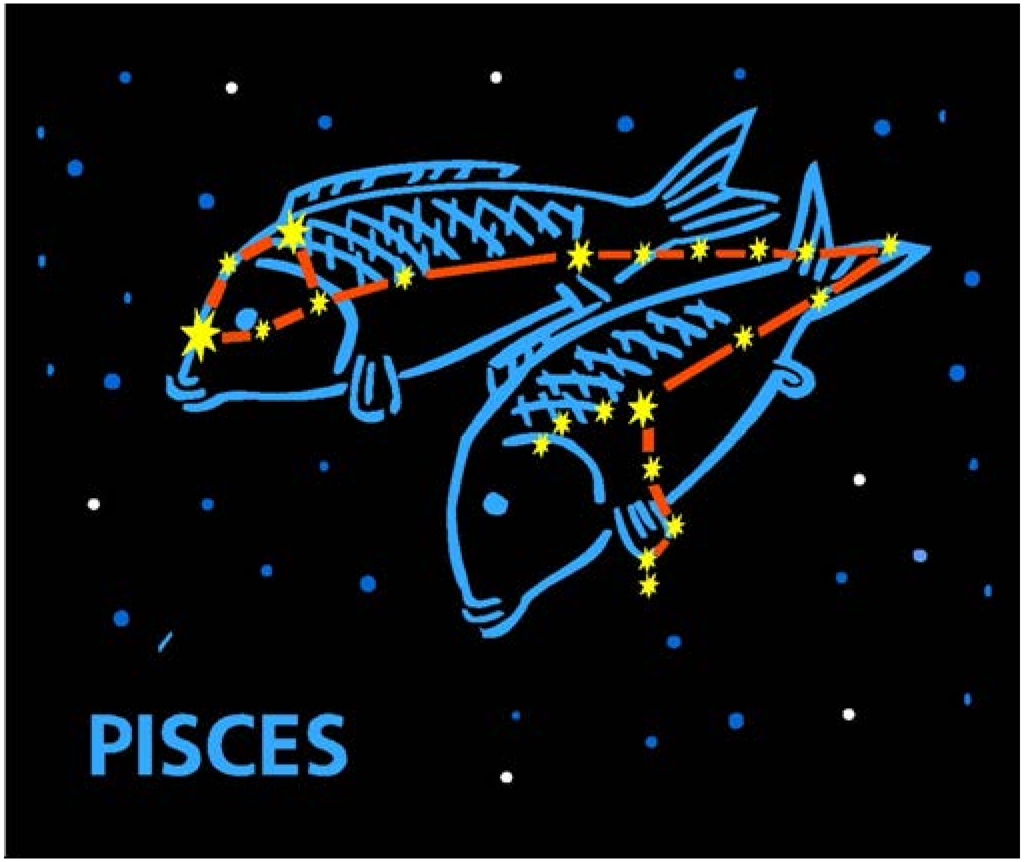
AQUARIUS

Morrow & Zawaski (Aug 2004)
camorrow@colorado.edu

PISCES



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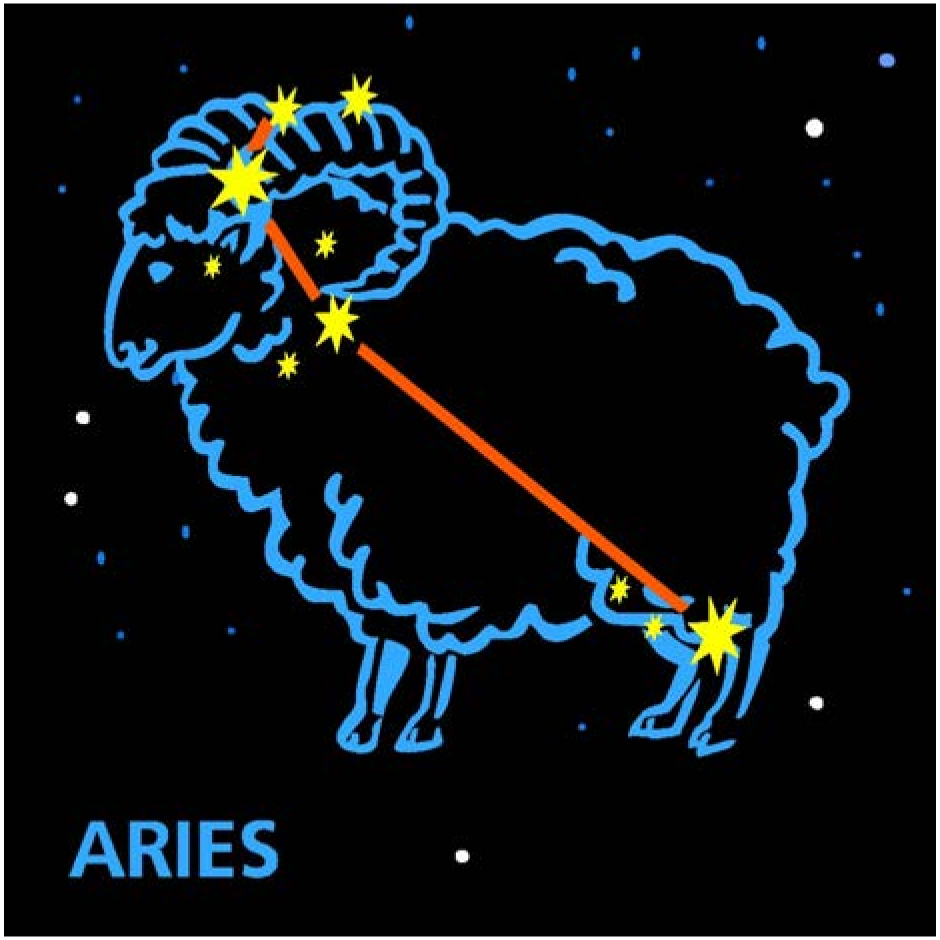
ARIES



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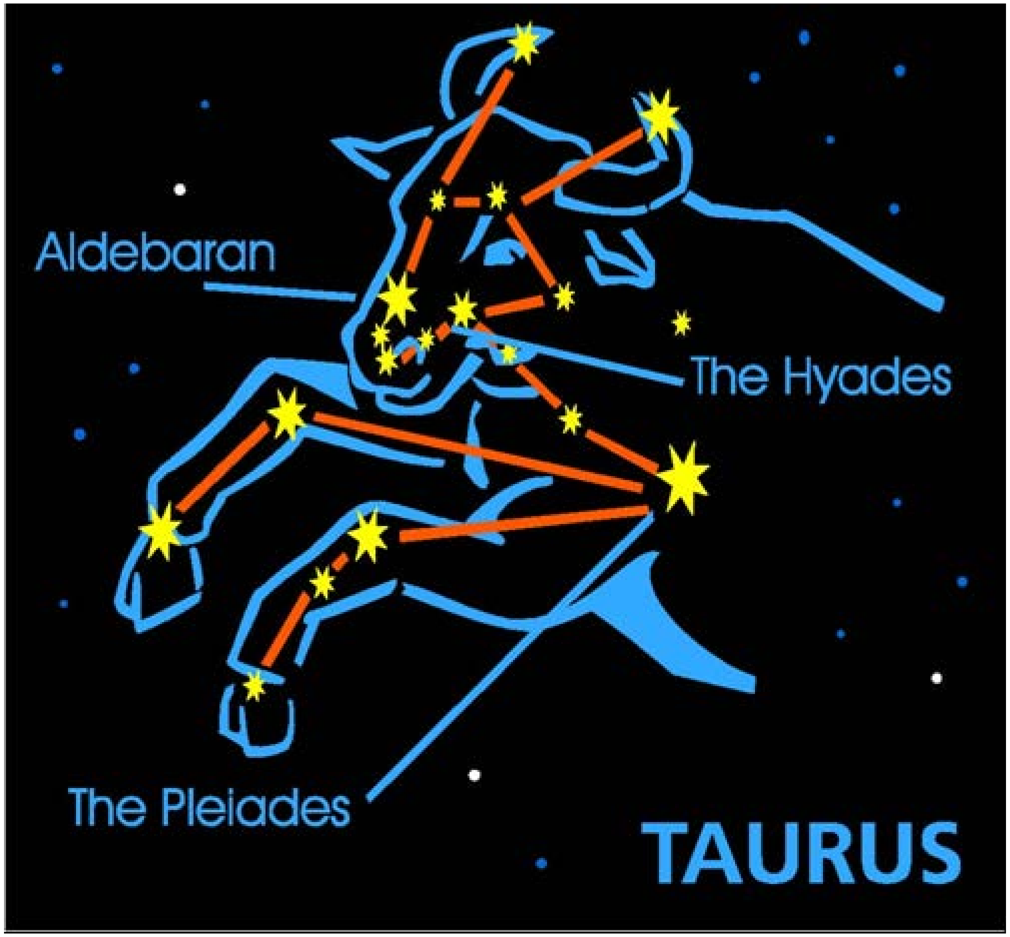
TAURUS



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GEMINI

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CANCER

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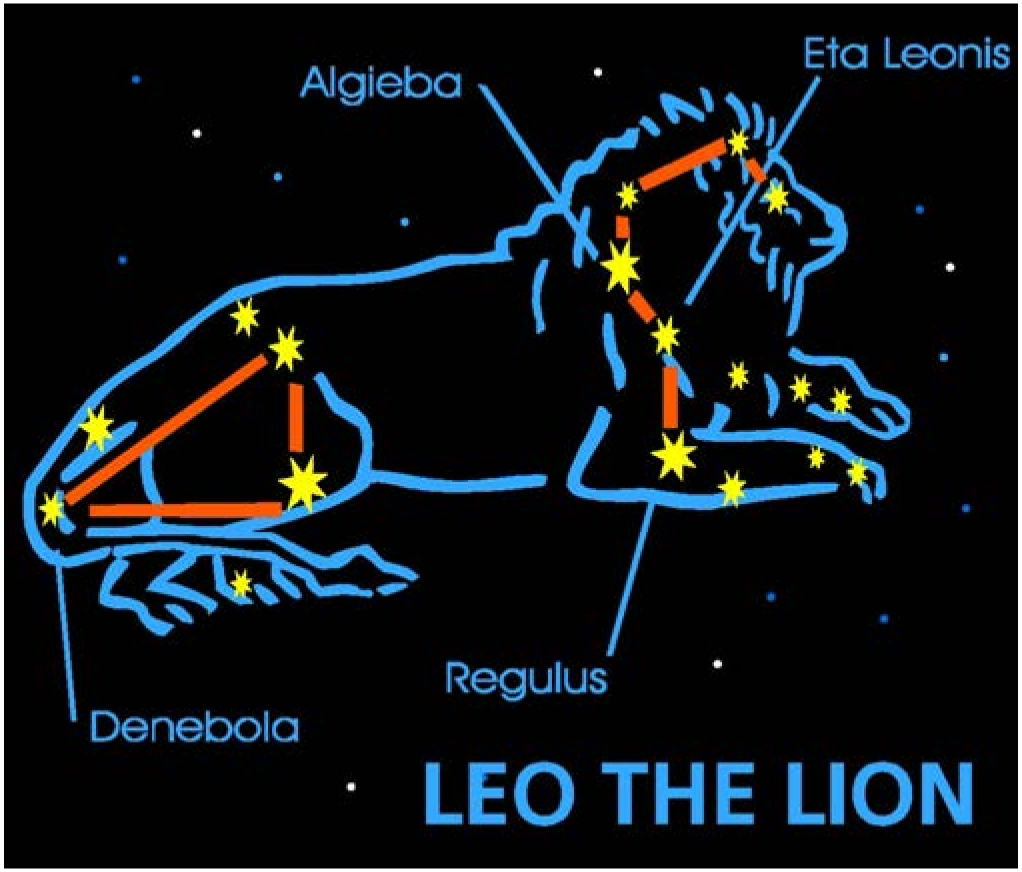
LEO



Morrow & Zawaski (Aug 2004)
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VIRGO

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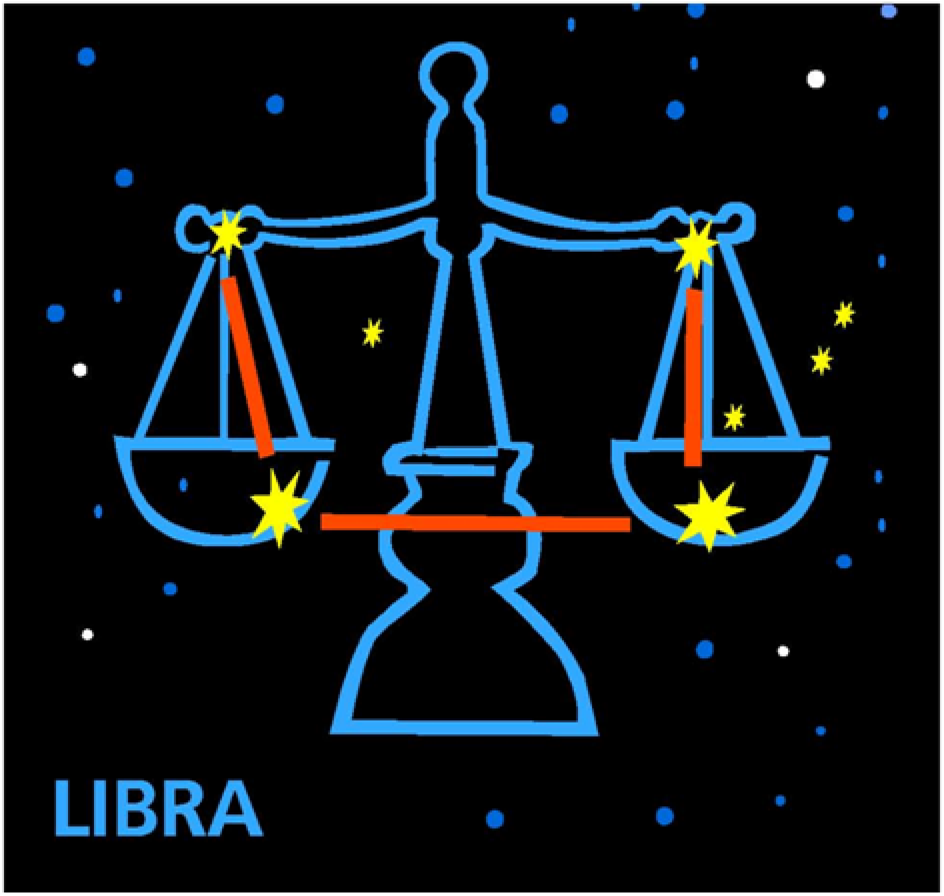
LIBRA



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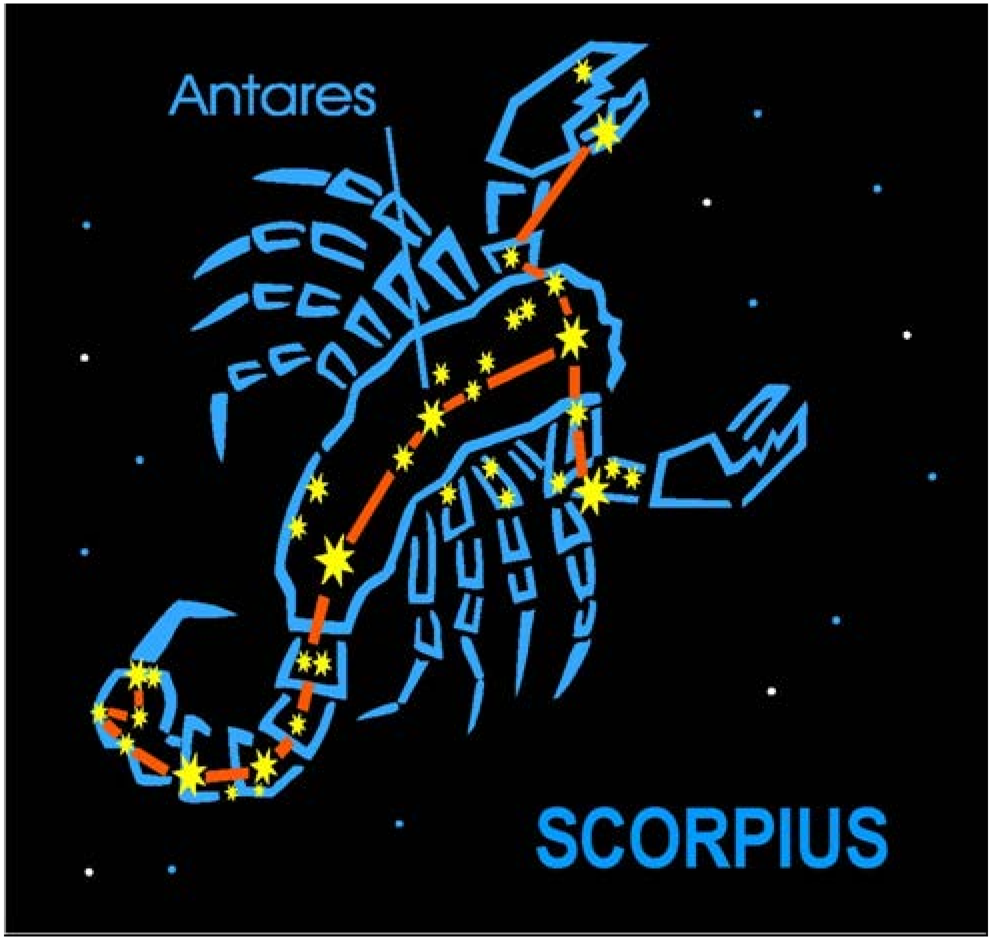
SCORPIUS



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Kinesthetic Astronomy: Earth's Rotation

GRADE LEVELS	3rd -8th; California Content Standards for 3rd and 5th
SUBJECTS	Earth Sciences, Astronomy
DURATION	Preparation: 20 minutes Activity: 15- 30 minutes
SETTING	Classroom

Objectives

In this activity students will

1.) understand why the sun rises in the east and sets in the west
2.) understand how the earth rotates and how long it takes for the earth to rotate
3.) discover that the stars appear to rise and set just like the sun does

Materials

- An object to represent the Sun at the center of the circle (i.e. lamp, yellow balloon, etc.)
- Twelve Zodiac Signs with instructions for assembly and set-up
- Painter's tape (if you are taping these signs to chairs or walls)
- Globe or inflatable Earth to show the distribution of continents on planet Earth
- Copies of the continents (1 set per student)
- Four Seasons Signs with dates of equinoxes and solstices

Preparation

- Print out the materials listed above
- Follow the diagram to set up your kinesthetic circle
- To mark the floor with where students should stand, use the painters tape or some other marker to put down a circle. Use 12 pieces of tape to represent each earth month

Vocabulary

- ❖ **Axis:** the center around which something rotates
- ❖ **Constellation:** an identifiable configuration of stars as seen from earth
- ❖ **Rotation:** a single complete turn
- ❖ **Rotational Period:** The amount of time a planet requires to make one complete spin about its axis. The earth has a 24 hour rotational period.
- ❖ **Solar System:** a sun with the celestial bodies that revolve around it in its gravitational field
- ❖ **Sunrise:** the daily appearance of the sun
- ❖ **Sunset:** the daily disappearance of the sun

Background Information

This activity begins with students turning themselves into the earth and then physically moving their bodies and engaging in critical thinking in order to figure out how the earth rotates. The activities aim to engage students in a kinesthetic understanding of the solar system.

Kinesthetic describes a sensation of bodily position, presence, or movement. Putting a spoonful of soup in our mouth is an everyday example of using a kinesthetic sense. We know where our mouth is even though we do not see it or touch it. We kinesthetically sense the presence and position of our mouth so that the soup spoon makes it in. You can kinesthetically sense the position and movement of other body parts as well.

Many people have a hard time interpreting drawn diagrams and understanding how the earth moves in relationship to the sun. In a 2008 California Academy of Sciences Survey we discovered that many adults don't know that the earth takes 365 days to travel around the sun. This concept was also shown in the Harvard- Smithsonian Center for Astrophysics in the 1987 Private Universe study that looked at why students have a hard time learning astronomy.

Some of the common misconceptions that students have are outlined in the paragraphs below with a follow up explanation for helping to correct that perception.

- **How many stars are in a solar system?** Many people believe that there is more than one star in our solar system and that the Solar System is the entire Universe. For example, many wrongly believe that Polaris (the Pole Star or North Star) is within the Solar System and closer than the planet Pluto. In reality Polaris is about 876,000 times more distant from our sun than Pluto.

- Many people have not perceived that stars (at all but polar latitudes) appear to rise and set just as the Sun does (due to Earth's rotation about its north-south axis). For some urban dwellers, even sunrise and sunset are uncommon experiences. **Stars rise and set just like the sun.**

- There is a common confusion between use of the terms "rotation" and "orbit". "Rotation" is often mistakenly used to describe the motion of Earth orbiting the Sun. It is important to make the distinction between these terms very clear. Each day Earth *rotates* once on its axis; each year Earth *orbits* the Sun. **Rotation is how a planet spins on its axis.**

- When asked whether people in China will see the same stars tonight as people in the US (if both are located at about the same latitude), many people answer "no". Earth's rotation makes noon change to midnight, and this takes only twelve hours. Earth's orbit around the Sun slowly changes the direction Earth's night side faces out into space. Meanwhile, in 12 hours Earth has not moved very much in its orbit around the Sun, and so the night side in China is facing almost the same direction out into space as the night side in the US. Thus the people in China will see the same stars tonight. **People looking at the sky at the same latitude on earth will see the same stars even if they are on opposite sides of the world.**

Activity Procedure

1.) Give students printouts of the earth's continents and have them tape them to their shirts with North America towards the top left. Explain that they are going to be the earth and will be hanging out in space for the rest of the activity.

2.) Once the students have become the earth, ask questions such as…
   a. Where is your equator? – around their belly
   b. Touch your north pole – head
   c. Where is your home? Is that in the northern hemisphere?
   d. What is on the other side of the earth from North America? – Asia

3.) Have your students stand around the kinesthetic circle and discuss the following questions with a partner.
   a. Which way is east and which way is west? [east is to the left, west is to the right]
   b. How does the Sun appear to move in the sky? [Rises in the east; Sets in the west]

4.) Have students face directly toward the symbolic Sun. Gesture with your hand from the middle of your face down along the front of you.
   a. What time would it be along a line that runs down the middle of your front? [Noon]
   b. Why is it noon? [The Sun is midway between east and west.]

5.) Have students face directly away from the Sun.
   a. Is the Sun on North America now? [No]
   b. What time is it now?" [Midnight] "What do you see? [Stars]
   c. What time is it along a line that runs along the middle of your back? [Noon]
   d. What would people there see in the sky? [The Sun]

6.) Call students' attention to how it can be different times at different places on Earth, and how there are 12 hours between their front and back.

7.) Have the students hold up their hands alongside their eyes to create a horizon line. Explain that what is behind their hands is out of sight.

8.) Have students make a 90-degree turn toward their east.
   a. What is low in your east? [stars]
   b. What is low in your west? [The Sun]
   c. What time of day is this when the Sun is low in your west? [Sunset]
   d. Why is this sunset? [Because the Sun is disappearing in the west.]
   e. Why does the Sun seem to disappear in the west? [Because I turn away from it.]

9.) Return to noon and ask: "So which way does Earth turn so that the Sun appears to set in the west and rise in the east." Give students time to work out the answer, using trial and error.

10.) Now guide everyone in rotating through a complete day. Start with the noon position, facing the Sun. Command students in sequence:
   a. Turn to sunset- what do you see? [the sun low in the west]
   b. Turn to midnight-- What do you see in your sky? [Stars]
   c. Come to sunrise- What do you see in your sky? [The Sun low in the east]

Discussion & Wrap-up Questions

1.) What do we call the turning of Earth that causes the Sun to rise and set? [Rotation]

2.) How long does it take Earth to rotate around one time? [24 hours = 1 day]

3.) Do people in Asia see the same stars that people in North America do? [Yes!]

4.) What is today's date in the US at 3pm? What would be the date in central China where it is 3am? [Tomorrow's date]

Extensions

Use the same kinesthetic set-up and combine this activity with other activities such as the Astronomical Meaning of a Year, Reasons for the Seasons, Moon Phases, Birthday Stars, Mars Opposition Dance.

Resources

Space Science Institute: www.spacescience.org
Astronomical Society of the Pacific: www.astrosociety.org/education.html

Correlated California State Content Standards

Grade Three

Earth Sciences

4a. Students know the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.

4e. Students know the position of the Sun in the sky changes during the course of the day and from season to season.

Grade Five

Earth Sciences

5a. Students know the Sun, an average star, is the central and largest body in the solar system

Correlated California New Science Standards

Kindergarten

K-PS3-1: make observations to determine the effect of sunlight on Earth's surface.

First Grade

1-ESS1-1: use observation of the sun, moon and stars to describe patterns that can be predicted.

1-ESS1-2: make observation at different times of year to relate the amount of daylight to the time of year.

Fifth Grade

5-ESS1-2: Represent data in graphical display to reveals patterns of daily changes in length and direction of shadow, day and night, and seasonal appearance of some stars in the night sky.

Greenland
Canada
A
United States
North Pacific Ocean
North Atlantic Ocean
México
Venezuela
Colombia
Brasil
Brazil
Perú
Bolivia
Chile
South Pacific Ocean
Argentina

Kinesthetic Astronomy: The Meaning of a Year

GRADE LEVELS	3rd -8th; California Content Standards for 3rd
SUBJECTS	Earth Sciences, Astronomy
DURATION	Preparation: 5-20 minutes Activity: 10- 20 minutes
SETTING	Classroom

Objectives

In this activity students will

1.) Understand the astronomical meaning of an earth year.
2.) Learn the difference between a rotation and an orbit.

Materials & Preparation

Use the same set up for the kinesthetic astronomy circle as seen in Earth's Rotation activity.

Vocabulary

- **Rotation:** a single complete turn
- **Orbit:** the path described by one celestial body in its revolution about another
- **Orbital period:** the time taken for a given object to make one complete orbit about another object; the earth takes 365 days to orbit the sun.
- **Solar System:** a sun with the celestial bodies that revolve around it in its gravitational field

Teacher Background Information

This part of the Sky Time lesson uses kinesthetic techniques to introduce Earth's orbit around the Sun and to construct the meaning of "orbital period." *NSF Indicators of Science & Engineering 2002* reports that about 50% of a representative sample of the U.S. public are unaware that it takes one year for Earth to orbit the Sun.

There is also a common confusion between use of the terms "rotation" and "orbit". "Rotation" is often mistakenly used to describe the motion of Earth orbiting the Sun. It is important to make the distinction between these terms very clear. Each day Earth *rotates* once on its axis; each year Earth *orbits* the Sun.

Activity Procedure

1.) Have students stand in the Kinesthetic Circle around the Sun. Ask the following questions:
   a. Who has a birthday closest to today?
   b. How many trips around the Sun have you (the birthday person) made in your life?
   c. Allow time for everyone to reflect on this question, making the connection between their age in years and the time it takes Earth to make a trip around the Sun.
   d. Poll the other students in the room- i.e. “How many have made 10 trips?”

2.) Tell students that Earth’s trip around the Sun is called an orbit.
   a. “What is the shape of Earth’s orbit around the Sun?” [An almost perfect circle.]
   b. This means Earth is always about the same distance from the Sun. (NOTE: Actually, Earth is a tiny bit closer to the Sun in Northern Hemispheric winter, but this does not cause the seasonal changes.)

3.) Define and demonstrate the difference between “orbit” and “rotation”. How many times does Earth *rotate* around its axis during one *orbit* around the Sun?” [365 times = 365 days.] (NOTE: Ask the question in this way to connect “time” and Earth’s motions.)

4.) Pose the following questions and give students time to discuss and discover with a partner.
   a. Which way does Earth orbit around the Sun?
   b. HINT: After the New Year, you would see Taurus in the night sky, and then later in the year you would see Leo in the night sky. Still later you would see Scorpio.
   c. How many say Earth orbits clockwise around the Sun? How many say counterclockwise? [Confirm that Earth’s orbit is counterclockwise around the Sun.]

5.) Have the students walk through one full orbit. Start with rotation and then begin to move in orbit around the Sun as well. Ensure all students are rotating and orbiting in the proper sense. Enjoy their smiles. Contain students who are moving recklessly.

6.) Allow time for recovery and re-focus attention by reviewing what students have learned.
   a. How long does it take Earth to orbit the Sun? [1 year = 365 days]
   b. Define the term “Orbital Period” as the *time* it takes one body to orbit another body.
   c. What is Earth’s orbital period? [1 year or 365 days]

Extensions

Use the chart in the teacher background information to compare and contrast the astronomical meaning of a year and a day for the different planets in our solar system. Have them write a story about how living on those planets might be different because of the seasons.

Resources

Space Science Institute: www.spacescience.org
Astronomical Society of the Pacific: www.astrosociety.org/education.html

Correlated California State Content Standards

Grade Three

Earth Science

3d. Students know that Earth is one of several planets that orbit the Sun and that the Moon orbits Earth.

Correlated California New Science Standards

Fifth Grade

5-ESS1-2: Represent data in graphical display to reveals patterns of daily changes in length and direction of shadow, day and night, and seasonal appearance of some stars in the night sky.

Middle School

MS-ESS1-1: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

Kinesthetic Astronomy: Mars Opposition Dance

GRADE LEVELS	3rd -8th; California Content Standards for 3rd
SUBJECTS	Earth Sciences, Astronomy
DURATION	Preparation: 5-20 minutes Activity: 10- 20 minutes
SETTING	Classroom

Objectives

In this activity students will

3.) Understand that planets take different amounts of time to move around the sun.
4.) Be able to explain why people on earth cannot always see all of the planets.
5.) Learn why planets were once called “wandering stars.”
6.) Define the terms: opposition, conjunction and retrograde in regard to astronomy.

Materials & Preparation

Use the same set up for the kinesthetic astronomy circle as seen in Earth’s Rotation activity. Mark an additional orbit outside of your earth orbit with 24 pieces of tape.

Vocabulary

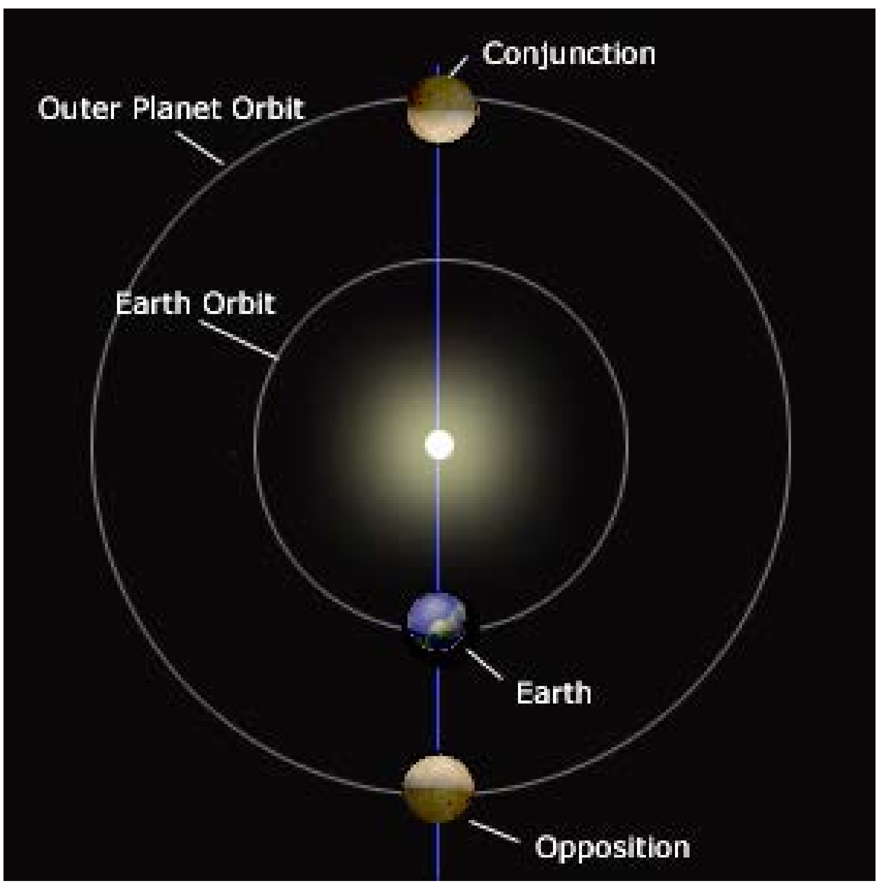
- **Conjunction:** a position when two or more celestial bodies appear to meet or pass in the same degree of the zodiac
- **Opposition:** a position when two celestial bodies are opposite in the sky from a certain viewpoint (usually on Earth).
- **Orbit:** the path described by one celestial body in its revolution about another
- **Orbital period:** the time taken for a given object to make one complete orbit about another object; the earth takes 365 days to orbit the sun.
- **Retrograde:** when a planet appears to be moving backwards; caused by the length of different orbits.
- **Solar System:** a sun with the celestial bodies that revolve around it in its gravitational field

Teacher Background Information

Opposition is a term used to indicate when one celestial body is on the opposite side of the sky when viewed from a particular place (usually the Earth).

An Opposition occurs when the planet is opposite from the Sun, relative to the Earth. At Opposition the planet will rise as the Sun sets and will set as the Sun rises providing an entire night of observation (just like with a full moon). Also at Opposition the planet comes physically closest to the Earth in its orbit so it appears as large as possible. For planets outside the Earth's orbit (Mars, Jupiter, Saturn, Uranus, Neptune and Pluto), the months around Oppositions are the best time to view these. Conversely, during a conjunction, a planet is in line with the sun and impossible to see at all.

A Mars year (orbital period) is equal to 2.135 Earth years. Therefore approximately every 2 earth years Mars is in opposition. When oppositions occur, it is ideal not only to observe the planets, but also to send spacecraft out to the planet. The first space craft that visited Mars was the Mariner in 1964. 2010 was the first year that NASA did not send a new spacecraft during its opposition since 1996.



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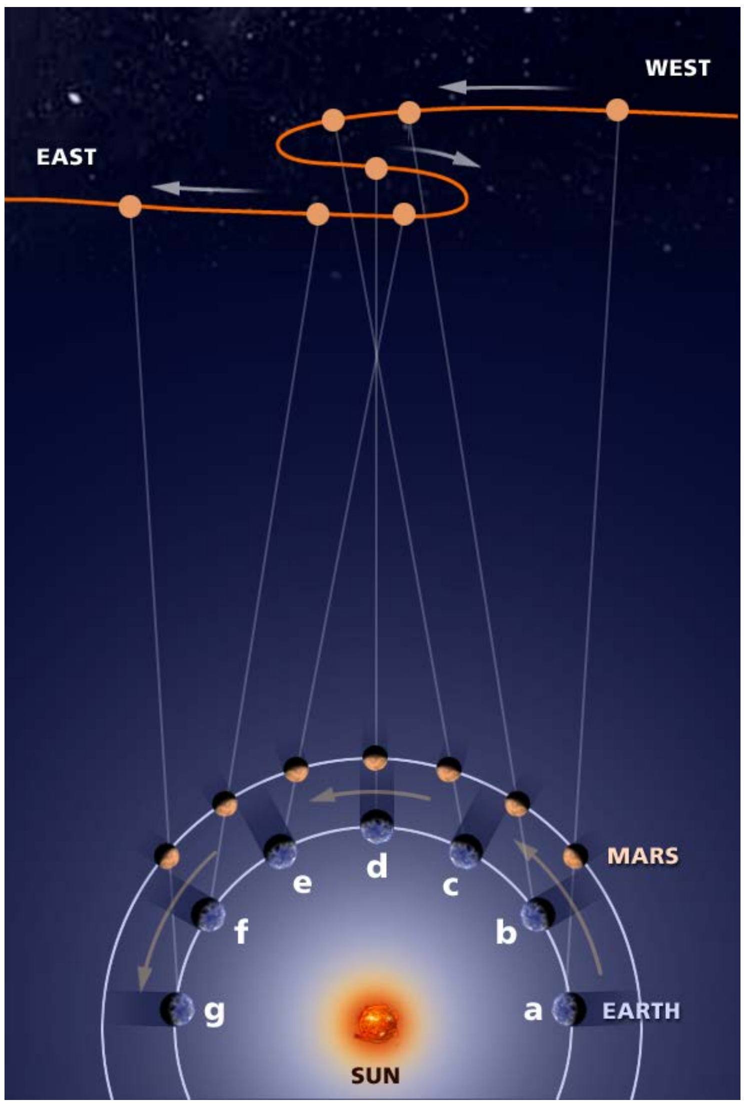
Looking up in the sky each night at the same time, usually you would observe that Mars is a little further east each night compared to the constellations. However, about every two years there are a couple of months when Mars appears to move from east to west when observed at the same time (retrograde motion).

This backward or retrograde motion was mysterious to the early observers, and led to the use of the word "planet", from the Greek term which means "wanderer".

It is in a short period including the time of opposition when Mars exhibits its retrograde motion to an observer on the Earth. As the Earth moves forward in its orbit, Mars will appear to slip backward compared to its more common eastward march across the sky.

http://mars.jpl.nasa.gov/allabout/nightsky/nightsky04-2003animation.html



Activity Procedure

1. Have two students volunteer- one to play the role of the Earth and the other to play the role of Mars. Everyone else can gather around the kinesthetic circle to observe the activity.

2. Have the students stand at Mars opposition (lined up with each other on the orbits).

3. Show the students how each piece of tape on the floor represents an Earth month.

4. Have the group clap out a slow beat. Each time there is a beat the planets step from one month to the next, pacing out their orbits. Once the planets have had the chance to make a few complete orbits, ask the students some questions.
   a. How often does Mars opposition happen? (once every 2 years)
   b. Can people on earth see Mars throughout the entire year?

5. Perform the "dance" again, pausing at different places (6 earth months, one earth year, etc.) to see how aligned Mars and Earth are.
   a. Have students illustrate progressive drawings of what they would see on earth as time goes by in their science notebooks.
   b. Why was Mars called the wandering star? (because it looked bright and changed orientation with the zodiac)

Extensions

- Use the "Planets in our Solar System" chart and have students calculate how often the other outer planets come into opposition with the earth.

- For the inner planets, have students try to figure out when they might be able to see them in the night sky. (Since Venus orbits closer to the Sun than the Earth, it will always be relatively close to the Sun from our perspective. It will either appear in the sky in the West, after the Sun has gone down in the evening. Or rise before the Sun in the East in the morning. That's why they call Venus the morning star).

Resources

Space Science Institute: www.spacescience.org
Astronomical Society of the Pacific: www.astrosociety.org/education.html
National Aeronautics and Space Administration (NASA): http://mars.jpl.nasa.gov/allabout/

Correlated California State Content Standards

Grade Five

Earth Sciences

5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

Correlated California New Science Standards

Middle School

MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

Glossary

- **asterism**: A prominent pattern or group of stars, typically having a popular name but smaller than a constellation. Examples are: Big Dipper, Summer Triangle
- **asteroid**: A rocky space object that can be a few feet wide to several hundred miles wide. Most asteroids in our solar system orbit in a belt between Mars and Jupiter.
- **astronomer**: Scientist who observes and studies planets, stars, and galaxies.
- **atmosphere**: All the gases that surround a star, like our Sun, or a planet, like our Earth.
- **atom**: The tiny building block that makes up all matter.
- **axis**: An imaginary straight line around which an object spins.
- **Big Bang**: A theory that says the universe began with a super-powerful explosion of concentrated matter and energy.
- **black hole**: An invisible object in outer space formed when a massive star collapses from its own gravity. A black hole has such a strong pull of gravity that not even light can escape from it.
- **Celsius**: A metric temperature scale in which water freezes at 0 degrees and boils at 100 degrees.
- **comet**: Frozen masses of gas and dust which have a definite orbit through the solar system.
- **constellation**: A group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure. Modern astronomers divide the sky into eighty-eight constellations with defined boundaries.
- **crater**: A hole caused by an object hitting the surface of a planet or moon.
- **dwarf planet**: A non-satellite body that fulfills only the first two of the three criteria for planet (see below).
- **ecliptic**: The apparent path that the Sun traces out in the sky during the year.
- **elliptical**: Shaped like an egg that has ends which are equal.
- **energy**: The power to do work.
- **Fahrenheit**: A scale on a thermometer where the freezing point of water is represented by 32 degrees and the boiling point is represented by 212 degrees.
- **galaxy**: A giant collection of gas, dust, and millions or billions of stars, held together by gravity.
- **gas**: A form of matter that is not a liquid or a solid. A gas will spread out to fill up all of the space that is open to it.
- **gravitational pull**: The attraction that one object has for another object due to the invisible force of gravity.
- **gravity**: The force of attraction between two objects that is influenced by the mass of the two objects and the distance between the two objects.

- **Kelvin**: A scale for measuring temperature where 0 Kelvin is equal to -273.16 degrees Celsius. Zero Kelvin is referred to as absolute zero, the point at which all motion within molecules comes to a stop.
- **kilometer**: 1,000 meters. A kilometer equals 0.6214 miles.
- **Kuiper belt**: A disc-shaped region of icy objects beyond the orbit of Neptune.
- **light year**: The distance light can travel in one year, which is 9,500,000,000,000 kilometers.
- **mass**: The amount of matter in an object.
- **matter**: Anything that has mass and occupies space.
- **meteor**: An object from space that becomes glowing hot when it passes into Earth's atmosphere.
- **meteorite**: A piece of stone or metal from space that falls to Earth's surface.
- **meteoroid**: A piece of stone or metal that travels in outer space.
- **moon**: A natural satellite of a larger object. See SATELLITE.
- **nuclear fusion**: A process where atoms are joined and tremendous amounts of energy are released.
- **orbit**: The path followed by an object in space as it goes around another object; to travel around another object in a single path.
- **particle**: A very, very tiny piece of matter such as an electron, proton, or neutron found inside of an atom.
- **physicist**: A person who studies physics.
- **physics**: The study of how objects (from the very tiny to the very big) behave. The science of matter and energy, and of interactions between the two.
- **planet**: The definition of planet set in 2006 by the International Astronomical Union (IAU) states that in the Solar System a planet is a celestial body that:
  - is in orbit around the Sun,
  - has sufficient mass to assume hydrostatic equilibrium (a nearly round shape), and
  - has "cleared the neighborhood" around its orbit.
- **planetarium**: A building in which images of stars, planets, and constellations are projected on the inner surface of a dome for public entertainment or education.
- **pole**: The point at either end of the invisible line known as the axis. Planets have a south pole and a north pole.
- **reflect**: To throw back light, heat, or sound.
- **revolve**: To move in an orbit or circle around something.
- **rotate**: To turn around a center point, or axis, like a wheel turns on a bicycle.

- **satellite**: An object that moves around a larger object. There are natural satellites such as moons and there are man-made satellites such as the Hubble Space Telescope.
- **sidereal day:** 23.93 hours; the time it takes Earth to rotate exactly 360 degrees. A **solar day** (the time from noon to noon the next day) is exactly 24 hours, but Earth must rotate slightly more than 360 degrees in one solar day because it revolves around the Sun.
- **solar**: Having to do with the Sun.
- **solar eclipse**: A shadow that falls on an area of Earth when the Moon moves between the Sun and Earth.
- **solar system**: The Sun and all of the planets, comets, etc. which revolve around it.
- **sunspot**: A dark area on the Sun's surface that is cooler than the area around it. Sunspots are caused by magnetic storms on the Sun.
- **supernova**: An explosion of a star that causes the star to shine millions of times brighter than usual.
- **telescope**: A device that creates a larger image of a far away object. Any of various devices, sometimes made with an arrangement of lenses, mirrors, or both, used to detect and observe distant objects by their emission, transmission, reflection, or other interaction with invisible radiation.
- **thermometer**: An instrument for measuring temperature.
- **universe**: The huge space that contains all of the matter and energy in existence.
- **weightless**: Having little or no weight; not feeling the effects of gravity.
- **zodiac**: The ring of constellations that lines the ecliptic,. The paths of the Moon and planets also lie roughly within the ecliptic, and so are also within the constellations of the zodiac.

Most definitions adapted from and courtesy of NASA Goddard Space Flight Center:

http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html

Others are adapted from NASA's Solar System Exploration site:

http://solarsystem.nasa.gov/

Correlated California Content Standards

Grade Three

Earth Sciences

4. Objects in the sky move in regular and predictable patterns. As a basis for understanding this concept:

- **a**. Students know the patterns of stars stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
- **b**. Students know the way in which the Moon's appearance changes during the four-week lunar cycle.
- **c**. Students know telescopes magnify the appearance of some distant objects in the sky, including the Moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than the number that can be seen by the unaided eye.
- **d**. Students know that Earth is one of several planets that orbit the Sun and that the Moon orbits Earth.
- **e**. Students know the position of the Sun in the sky changes during the course of the day and from season to season.

Grade Five

Earth Sciences

5. The solar system consists of planets and other bodies that orbit the Sun in predictable paths. As a basis for understanding this concept:

- **a.** Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.
- **b.** Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.
- **c.** Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Correlated New California Content Standards

First Grade

1-ESS-1. Use observations of the sun, moon and stars to describe patterns that can be predicted.

Fourth Grade

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

Fifth Grade

5-ESS-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.
5-ESS-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Middle School

MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

Classroom Resources

Books, articles and web sites teachers may find useful.

Books

Moon Books

- **Long Night Moon** / Cynthia Rylant; illustrated by Mark Siegel. New York, NY: Simon & Schuster Books for Young Readers, 2004. 40 pages, color illustrations
  Native American tradition of naming the full moons, each month's moon has a different name and meaning.

- **Faces of the Moon** / Bob Crelin; illustrated by Leslie Evans. Watertown, MA: Charlesbridge, 2009. 36 pages, color illustrations

- **Papa, Please Get the Moon for** Me / Eric Carle. New York, NY: Simon & Schuster Books for Young Readers, 1986. ??pages, color illustrations

Cycles in the Sky

- **Cycles: An Introduction to Astronomy and Time** / Jay Ryan. San Francisco, CA: The Astronomical Society of the Pacific, 1997. 32 pages, graphic novel, non-fiction

- **What Makes Day and Night** / Franklyn M. Branley; illustrated by Arthur Dorros. New York, NY: HarperCollins Publishers, 1986. 32 pages, color illustrations
  Illustrates activities to do with the class and has helpful diagrams that would be great for ELLs.

- **Children's Book: Zoo in the Sky**/ Jacqueline MItton and Christina Balit. National Geographic Children's Books 2006. 32 pages, colorful illustrations

Space Exploration

- **Boy, Were We Wrong about the Solar System** / Kathleen V. Kudlinski; illustrated by John Rocco. New York, NY: Dutton Children's Books, 2008. 32 pages, color illustrations

- **Look to the Stars** / Buzz Aldrin; illustrated by Wendell Minor. New York, NY: G.P. Putnam's Sons, 2009. 40 pages, color illustrations
  A history of flight from the Wright Brothers to space flight, with a quick stop for early astronomers and physicists.

- **Reaching for the Moon** / Buzz Aldrin; illustrated by Wendell Minor. New York, NY: Collins, 2005. 36 pages, color illustrations
  Biography of Buzz Aldrin's life focusing on his life as a child and his path to becoming an astronaut

- **T Minus: The Race to the Moon** / Jim Ottaviani, Zander Cannon, Kevin Cannon. New York, NY: Aladdin, 2009. 128 pages, graphic novel
  Historic fiction covering the race to the moon, For advanced readers, but excerpts appropriate for any age, Page 100 good as a story seed

- **You Are the First Kid on Mars** / Patrick O'Brien. New York, NY: G. P. Putnam's Sons, 2009. 32 pages, color illustrations
  A fictional book about a boy traveling to Mars, beautiful illustrations

Comets and Other Things

- **When I Heard the Learn'd Astronomer /** Walt Whitman; illustrated by Loren Long. New York, NY: Simon & Schuster Books for Young Readers, 2004. 32 pages, color illustrations

- **Pieces of Another World** / Mara Rockliff; illustrated by Salima Alikhan. Mt. Pleasant, SC: Sylvan Dell Publishing, 2005. 32 pages, color illustrations

- **Sunshine on My Shoulders** / John Denver; illustrated by Christopher Canyon. Nevada City, CA: Dawn Publications, 2003. 32 pages, color illustrations
  Illustrated book of a John Denver song, uses descriptive language to describe how the sun makes a child feel, Sheet music included, Could follow with students writing lyrics for how the sun makes the earth feel

- **The Swamps of Sleethe: Poems from Beyond the Solar System** / Jack Prelutsky; illustrated by Jimmy Pickering. New York, NY: Alfred A. Knopf, 2009. 40 pages, color illustrations
  Poems written about fictional planets, for creative writing samples

Curricula and Activity Books

- **Picture-Perfect Science Lessons: Using Children's Books to Guide Inquiry, 3-6** / Karen Rohrich Ansberry and Emily Morgan. Arlington, VA: NSTA Press, 2005. 304 pages, lesson plans

- **More Picture-Perfect Science Lessons: Using Children's Books to Guide Inquiry, K-4** / Karen Ansberry and Emily Morgan. Arlington, VA: NSTA Press, 2007. 304 pages, lesson plans

Web Resources

Astronomy & Cosmology:

Nine Planets: http://www.nineplanets.org/
The Cosmology Primer:
http://preposterousuniverse.com/writings/cosmologyprimer/faq.html
FAQ's for Cosmology: http://www.astro.ucla.edu/~wright/cosmology_faq.html#ct2
Ask an astrophysicist:
http://imagine.gsfc.nasa.gov/docs/ask_astro/ask_an_astronomer.html
Universe Today: http://www.universetoday.com/
Sky and Telescope: http://www.skyandtelescope.com/
Space Weather Center: http://www.spaceweathercenter.org/

Observing:

Space Weather: http://spaceweather.com/
Heaven's Above: http://www.heavens-above.com/
Star Names: http://www.naic.edu/~gibson/starnames/
Star of the Week: http://stars.astro.illinois.edu/sow/sowlist.html

Images:

Astronomy Picture of the Day: **http**://apod.nasa.gov/apod/
Photojournal: http://photojournal.jpl.nasa.gov/

Teacher Resources:

Adler Planetarium: http://www.adlerplanetarium.org/educate/resources
Astronomical Society of the Pacific:
http://www.astrosociety.org/education/activities/activities.html
Pacific Science Center: http://www.pacificsciencecenter.org/Astro-Adventures/education/curricula/astro.html
NASA for Educators: http://www.nasa.gov/audience/foreducators/index.html
Hawai'I Space Grant Consortium: http://www.spacegrant.hawaii.edu/class_acts/

The Naturalist Center has also put together booklists on astronomy, which you can access here: www.calacademy.org/teachers/upload/docs/astronomyresourcelists.pdf/

Online Activities

Astronomy for Kids
http://www.kidsastronomy.com/
Find out about the solar system or space exploration, test your knowledge of astronomy with a crossword puzzle, play games, and just have fun at this great web site!

Design a Space Station
http://www.childrensmuseum.org/cosmicquest/spacestation/index2.html
Do you know what it takes to live in space? This fun web site lets you design a working space station that astronauts can live in for up to several months. You'll find out about energy sources, water requirements, and food needs in an interactive game.

National Geographic – Pluto's Secret
http://kids.nationalgeographic.com/Games/ActionGames/Plutos-secret
Play this fun game with Nat and Geo to find out why Pluto is no longer considered to be a planet.

The Space Place
http://spaceplace.jpl.nasa.gov/
Great web site for kids as they create projects, play games, solve puzzles and more all relating to space.

A Virtual Journey into the Universe
http://library.thinkquest.org/28327/
Once you're inside the site, click on a planet to find out more information. Lots of images and animation help to highlight your tour of the universe while at the same time providing loads of information.

References

Background information collected while researching scientific concepts.

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Astronomical Society of the Pacific. Astronomy from the Ground Up: http://astrosociety.org/afgu/index.html

Barringer Crater Company. http://www.barringercrater.com/about/history_1.php

California Academy of Sciences, Department of Inertebrate Zoology and Geology. *Collections Database:* http://researcharchive.calacademy.org/research/izg/CollectionsDatabases/Meteorites.htm

Dibon-Smith, Richard. "The Constellations": http://www.dibonsmith.com/menu.htm

Exploratorium. "Making a Sun Clock": http://www.exploratorium.edu/science_explorer/sunclock.html

Franklin Institute. "Foucault's Pendulum": http://www.fi.edu/time/Journey/Pendulum/

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NASA/MSU-Bozeman CERES Project. "Sky Paths: Studying the Movement of Celestial Objects": http://btc.montana.edu/ceres/html/SkyPaths/orbits1.html

National Optical Astronomy Observatory. "Classroom Resources": http://www.noao.edu/education/teachers.html

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Patterson, Claire. Age of meteorites and the earth. Geochimica et Cosmochimica Acta, v. 10, pp. 230 – 237. 1956.

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Space Science Institute. "Science Education": http://www.spacescience.org/education/instructional_materials.html

St. John, James. "Octahedrite": http://www.newark.osu.edu/facultystaff/personal/jstjohn/Documents/Rocks-from-Outer-Space/Octahedrite.htm

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