National Aeronautics and
Space Administration

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Hampton, VA 23681-2199

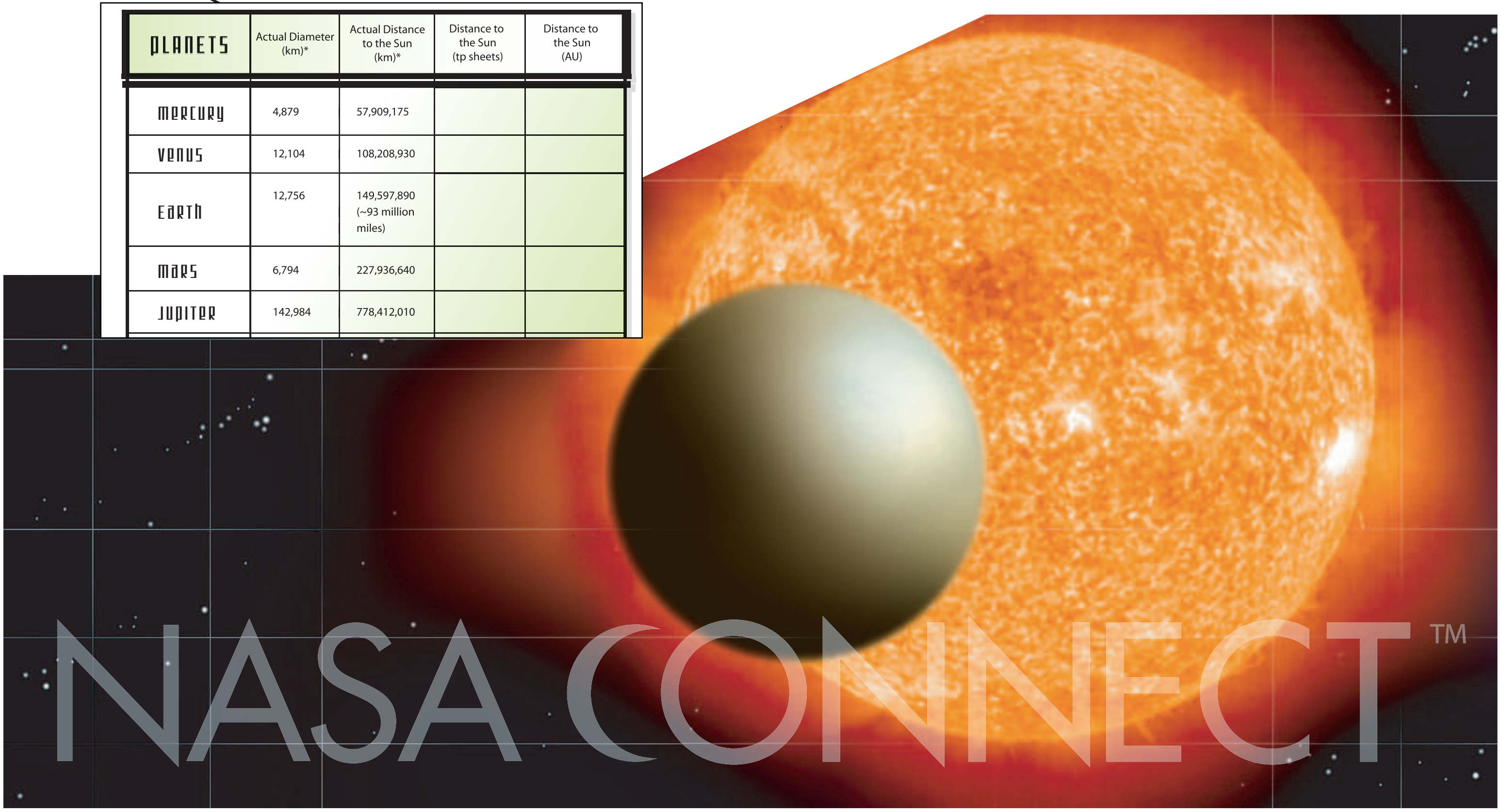
Educational Product
Educators | **Grades 6-8**
EG-2004-03-05-LARC

NASA CONNECT™

VENUS TRANSIT

An Educator Guide with Activities in Mathematics, Science, and Technology

PLANETS	Actual Diameter (km)*	Actual Distance to the Sun (km)*	Distance to the Sun (tp sheets)	Distance to the Sun (AU)
MERCURY	4,879	57,909,175		
VENUS	12,104	108,208,930		
EARTH	12,756	149,597,890 (~93 million miles)		
MARS	6,794	227,936,640		
JUPITER	142,984	778,412,010		



NASA CONNECT™: *Venus Transit* is available in electronic format through NASA Spacelink - one of NASA's electronic resources specifically developed for the educational community. This publication and other educational products may be accessed at the following address:
http://spacelink.nasa.gov/products

A PDF version of the educator guide for NASA CONNECT™ can be found at the NASA CONNECT™ web site: **http://connect.larc.nasa.gov**

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www.wildridge.com

www.aiaa.org

International Technology Education Association
www.iteawww.org

Aerospace Education Coordinating Committee
www.nasa.gov

www.cnu.edu

www.nctm.org

National Science Teachers Association
www.nsta.org

http://knowitall.org

NEC Foundation of America
www.nec.com

NASA CONNECT™

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AIAA FOUNDATION Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

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Program Overview

SUMMARY AND OBJECTIVES

In NASA CONNECT™: Venus Transit, students will learn about the importance of using scale models to represent the size and distance of objects in the solar system and beyond. They will be introduced to the astronomical unit (AU), the baseline distance from the Earth to the Sun, which astronomers use to determine the relative distances from the Earth to other planets, stars, asteroids, and objects in space. They will also discover fascinating facts about the Venus Transit, a celestial and historical event, which helped astronomers determine the scale of the solar system. By conducting inquiry-based and web activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

STUDENT INVOLVEMENT

Inquiry-Based Questions

Host, Jennifer Pulley, and NASA scientists will pose inquiry-based questions throughout the program. These questions allow the students to investigate, discover, and critically think about the concepts being presented. When viewing a videotape or DVD version of NASA CONNECT™, educators should pause the program at the designated segments so students can answer and discuss the inquiry-based questions. During the program, Jennifer Pulley and NASA scientists and engineers will indicate the appropriate time to pause the tape or DVD. For more information about inquiry-based learning, visit the NASA CONNECT™ web site, **http://connect.larc.nasa.gov/**

Teacher Note: It is recommended to preview the program before introducing it to your students so that you can become familiar where the pauses occur.

Hands-On Activity

The hands-on activity is teacher created and aligned with the National Council of the Teachers of Mathematics (NCTM) Standards and the National Science Education (NSES) Standards. Students will use measurement, ratios, and graphing to construct a model of the solar system and determine the relationship of each planet to the Sun.
They will explore the scales needed to represent the size of the planets and the distances to the Sun.

* The following measurements and their abbreviations appear in this educator guide: AU (astronomical unit), cm (centimeter), ft (feet), in. (inch), m (meter), and km (kilometer).

Squeak Extrasolar Challenge Web Activity

The activity is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science (NSES) Standards, and the International Technology Education Association (ITEA) Standards. Students will be able to create and study an extrasolar Norbanian system. They will make measurements on their system and analyze the results by plotting and taking ratios to show their system follows Kepler's laws and they will scale their system distances in Norbanian Astronomical Units (NAU).

RESOURCES

Teacher and student resources support, enhance, and extend the NASA CONNECT™ program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions. In addition to the resources listed in this educator guide, the NASA CONNECT™ web site ***http://connect.larc.nasa.gov*** offers online resources for teachers, students, and parents.

hands-on activity

BACKGROUND

The story of the Transit of Venus is one of Herculean efforts overcoming immense challenges and momentous scientific discoveries that shaped the very way we view our place in the universe. It takes place over hundreds of years and involves some of the most creative minds in science.

The story begins with a quest for one of astronomy's holy grails, the accurate size measurement of the solar system. The determination of the immensity of space had eluded astronomers for thousands of years. Around 300 B.C., Aristachus of Samos attempted to derive the distance to the Sun by observing the first quarter Moon. Using concepts of geometry and the best observing techniques available at the time, he estimated the distance to be about 20 Earth-Moon distances. Around 200 B.C., Eratosthenes, using data acquired during lunar eclipses, attempted to measure the Earth-Sun distance and came up with a value of about 83 million miles. Though these were major achievements for their time, we know today that the true distance is about 93 million miles. The prediction of the passage (transit) of Venus across the face of the Sun would be the key to deriving the distance to the Sun, the "Astronomical Unit" or AU. Johannes Kepler's understanding of the orbital behavior of celestial objects (his now famous three laws of planetary motion) made this prediction possible. Edmond Halley, who discovered the famous comet, developed the first detailed plan for calculating the AU from transits of the Sun and a concept called parallax. Parallax is the apparent displacement, or difference of position, of an object, as seen from two different stations, or points of view. By observing the apparent shift in position of Venus against the background of the solar disk, as seen from two different places on Earth, one can, using a bit of trigonometry, derive the distance to Venus, which when coupled with Kepler's 3rd law of planetary motion, will yield the distance from the Sun to all the planets.

In clear weather, Venus Transits are visible to the naked eye or with a small telescope and thus have been the subject of popular and scientific interest since they first came to attention in the 1600s. Their main scientific use, before the advent of radar, was the measurement of the astronomical unit, or the Earth-Sun distance, as you learned earlier. From a cultural and popular scientific standpoint, they are, like the appearance of a comet or a great meteor shower or an eclipse, an opportunity for the intellectually curious to witness a relatively rare celestial phenomenon. Events like the Venus Transit serve to stimulate human and societal interest in the planets and the solar system. They can be thought of as early counterparts of today's planetary system explorations by spacecraft and powerful ground-based telescopes.

The biggest activity surrounding the June '04 Venus Transit is probably the world-wide network of amateur astronomers who will repeat the measurement of the astronomical unit by using the same approach as the earliest observers. An innovative aspect this time, however, not available in 1882 during the last Venus Transit, is the widespread use of the Internet to organize international participation and the ease of access to the computational tools needed to make the parallax calculations, some of which are already up and running on the Web!

There also will be a few astronomical researchers who will try to exploit state-of-the-art observing tools to see what can be learned about the use of transits to investigate planets around other stars. Transits are currently being used to search for such planets. In fact, a planned NASA Discovery mission called Kepler, led by investigators at NASA Ames Research Center in California, is focused on this application. Its spacecraft-borne telescope above the Earth's atmosphere will be capable of sensitive detection of the slight stellar dimmings related to transits. Transits have actually already been used to detect, from the ground, one extrasolar gas giant planet. Kepler is aimed at extrasolar terrestrial planet detection, but the next obvious questions about planets' atmospheres will not be answered.

Planetary atmospheres contain evidence of gases such as water vapor and ozone that are critical properties of life-supporting planets. Can scientists figure out a way to use transits to remotely probe these very distant atmospheres? Perhaps this Venus Transit will lead to some new technique or measurement that will allow future researchers to further study the terrestrial planets discovered during the Kepler mission and other longer range, planet-finding missions.

Not to be overlooked is what reminder the Venus Transit can provide us regarding the Earth's place in the Cosmos. The tiny dot crossing the solar disk is a terrestrial planet with an atmosphere, and yet it is far from an "Earth." Venus, once called a "twin-Earth," in part because of its similar size and distance from the Sun (0.73 AU as opposed to 1.0 AU), is now known to be a place that is extremely hostile to life for reasons still under study. Its tremendously dense, hot atmosphere makes the surface conditions equivalent to pressures one would experience 1 km beneath the surface of the ocean but surrounded by scorching, caustic vapors. Venus's atmosphere, moreover, is almost devoid of water vapor. Whether the conditions on Venus are purely a result of its slightly closer proximity to the Sun or involve other effects caused by its original makeup of elements or its absence of a planetary magnetic field, remain to be determined by future investigations. One can speculate how our own "pale blue dot" would look to some distant alien astronomer as it passed across the Sun in transit and whether it has ever been observed!

INSTRUCTIONAL OBJECTIVES

The student will

- use measurement to study the placement of the planets in our solar system.
- use ratios to determine the scales needed to represent the size of the planets and their distances from the Sun.
- compare and contrast two graphs that visually represent the distances of the planets to the Sun.

NATIONAL STANDARDS

NCTM Mathematical Standards

Number and Operations

- Understand numbers, ways of representing numbers, relationships among numbers, and number systems.

Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement.

Representation

- Use representations to model and interpret physical, social, and mathematical phenomena.

Algebra

- Use mathematical models to represent and understand quantitative relationships.
- Understand patterns, relations, and functions.

NSES Science Standards

Science as Inquiry

- Abilities to do scientific inquiry

Earth and Space Science

- Earth in the solar system

NASA RELEVANCE

The astronomical unit is the baseline distance that is used to determine the distances of other planets, stars, asteroids, and other objects in space relative to the Earth. Without an accurate measurement of the Sun-Earth distance, NASA satellites and spacecraft would have a difficult time reaching their destinations. Knowing how far a spacecraft must travel is even more critical when astronauts eventually explore Mars and other planets.

PREPARING FOR THE ACTIVITY

Student Materials

- calculator
- metric ruler
- planet templates
- Scale Model Chart (SMC)
- scissors
- tape (for repair if needed and also to attach planets to the toilet paper)
- toilet paper (referred to as "tp" in the rest of the activity)

Note: *Toilet paper size varies. Scales were created by using sheets 10.16 cm (4 in.) long, the standard size of most toilet papers. One to two rolls of toilet paper are plenty for the activity.*

Time for Activity

- 60 minutes (watching the video and discussing the inquiry-based questions)
- 120 minutes (the activity)
- 60 minutes (the extension activity – optional)

THE ACTIVITY

Brief Description

In this activity, students will review the order of the planets and discuss the individual planet distances from the Sun. The importance of the scale used to measure the distances from the Sun will be investigated and conversion techniques will be discussed and used.

Lesson Description

ENGAGE

Students should view the program, NASA CONNECT™: *The Venus Transit* and answer all inquiry-based and math related questions from the video.

Teacher led discussion:

Review the astronomical unit, the distance from the Earth to the Sun, which is approximately 93 million miles or 149 million kilometers. You may wish to mention that the astronomical unit is not practical to use when calculating distances outside the solar system. In those cases, astronomers use light years. One light year equals 63,240 AU.

EXPLORE

Working in groups, students will complete the activity by using the Scale Model Chart (SMC) and the Planet Templates.

- Assign each group a planet. Each group should cut out the assigned planet by using the Planet Template.

Note: *The planet sizes and the distances of the planets from the Sun are not to scale. If the correct planet sizes were used for this activity, the planets would be merely dots. Teachers should not inform students about this discrepancy at this time. Students will address this issue during the student discussion questions.*

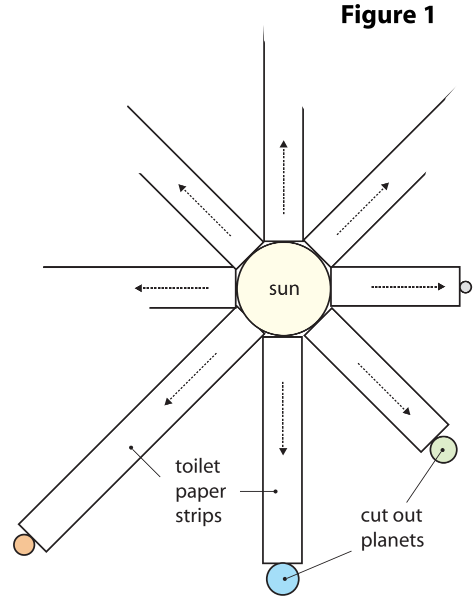
Note: *If you wish to make a cutout of the Sun, the diameter of the cutout should be approximately 200 cm.*

- The scale in toilet paper sheets for this activity is 1 tp sheet = 30,102,900 km. Using the scale, students should complete column four on the Scale Model Chart (SMC). Students should round their answers to the nearest tenth of a sheet. Groups should check each other's work to make sure all values are correct.

- The scale of the solar system model for this activity is 1 AU = 5 tp sheets. Using the scale, students should complete column five on the SMC. Students should round their answers to the nearest tenth of an AU. Groups should check each other's work to make sure all values are correct.

- After completing the SMC, each group should roll out the number of tp sheets needed for its assigned planet.
- Students are directed to the "staging area" (which may be in the gym, cafeteria, or halls if wide enough; however, being outside works best). Place the Sun in a central or corner position (approximately 22.5 m or 74 ft will be needed in one direction). Students should attach their pre-measured toilet paper strip to the Sun and let it extend outward in various directions, placing their assigned planet on the end of the strip. See Figure 1.

Figure 1



Student discussion *(within the classroom)*:

1. What is the importance of using scale models to study the solar system?

2. Study the last column on the Scale Model Chart. Does this column represent the actual distance of the planets from the Sun in terms of astronomical units? What does it tell you about scaling?

3. The planet cutouts that you used for this activity are not to scale compared to the distance of the planets from the Sun. If drawn to scale, would the planet cutouts be larger or smaller than the cutouts you used? Why? To test your hypothesis, calculate to scale, the diameter of the planet Earth and Jupiter in centimeters. Remember the scale for this activity is 1 tp sheet = 30,102,900 km. Each toilet paper sheet is 10.16 cm (4 in.) long. Find the actual diameter of each planet on the Scale Model Chart.

4. Calculate the distance of your assigned planet in centimeters. Remember, the length of one toilet paper sheet is 10.16 cm.

EXPLAIN

Each group will create two graphs, Distance to the Sun (in km) vs. Planets in the Solar System and Distance to the Sun (in tp sheets) vs. Planets in the Solar System. Students should choose the appropriate type of graph and scale for each.

Teacher Note: A histogram would be an appropriate graph display. By using a full 8.5 in. x 11 in. sheet, students could make the first graph a 200,000,000-km scale and the second graph a 5-sheet scale.

Journal Write: Students should compare and contrast the two graphs. Can the scale affect the shape of the graph? Which graph gives a better sense of how far the planets are from the Sun? Which representation, the solar scale model or the graphs, provides a better sense of how large the solar system is?

EXTEND

Working in groups, students will create a solar system for Norbert by using the following planets: Kog, Margm, Punka, Spork, Hharndx, Quonk, Quadro, Zotalia (home of Zot), and Norbania (home of Norbert). Determine the size, location, and scale for this system. Generate a diagram with labels and appropriate placement for the planets and the system. Develop a name for your system. After your system has been evaluated by a teammate or another group, you may e-mail your diagram to <**http://connect.larc.nasa.gov**> where students from across the country can view it.

EVALUATE

Each group will evaluate another group's system and determine whether the system meets the following criteria:

- title
- location in universe stated
- scale noted/checked
- size of system indicated
- all labeling in place

Teacher note: *Points may be assigned for this process or corrections can be made.*

Student Handout

Scale Model Chart

Planets	Actual Diameter (km)*	Actual Distance to the Sun (km)*	Distance to the Sun (tp sheets)	Distance to the Sun (AU)
Mercury	4,879	57,909,175		
Venus	12,104	108,208,930		
Earth	12,756	149,597,890 (~93 million miles)		
Mars	6,794	227,936,640		
Jupiter	142,984	778,412,010		
Saturn	120,536	1,426,725,400		
Uranus	51,118	2,870,972,200		
Neptune	49,528	4,498,252,900		
Pluto	2,360	5,905,376,200		

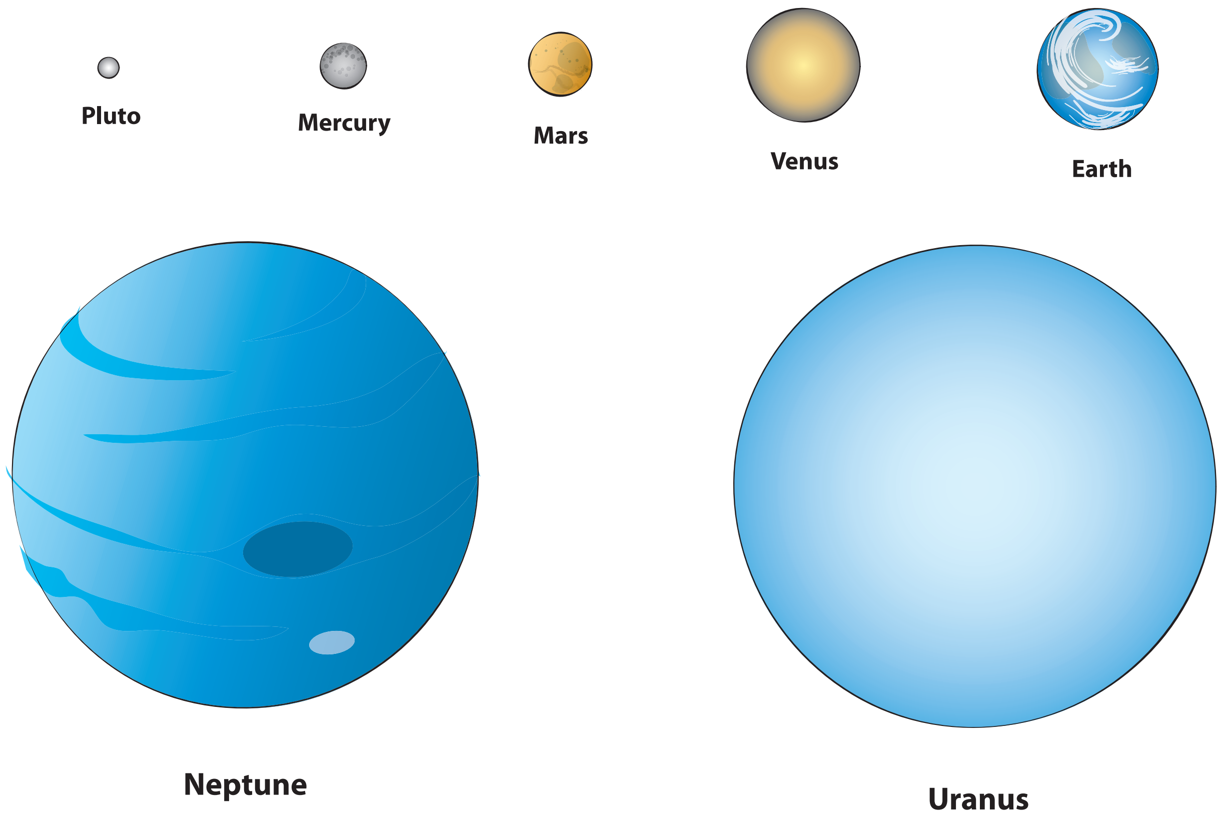
* Actual planet data used from NASA JPL web site:
http://sse.jpl.nasa.gov/planets/index.cfm

Solar System Model Scale: 1 tp sheet = 30,102,900 kkm

1 tp sheet = 10.16 cm (4 in.)

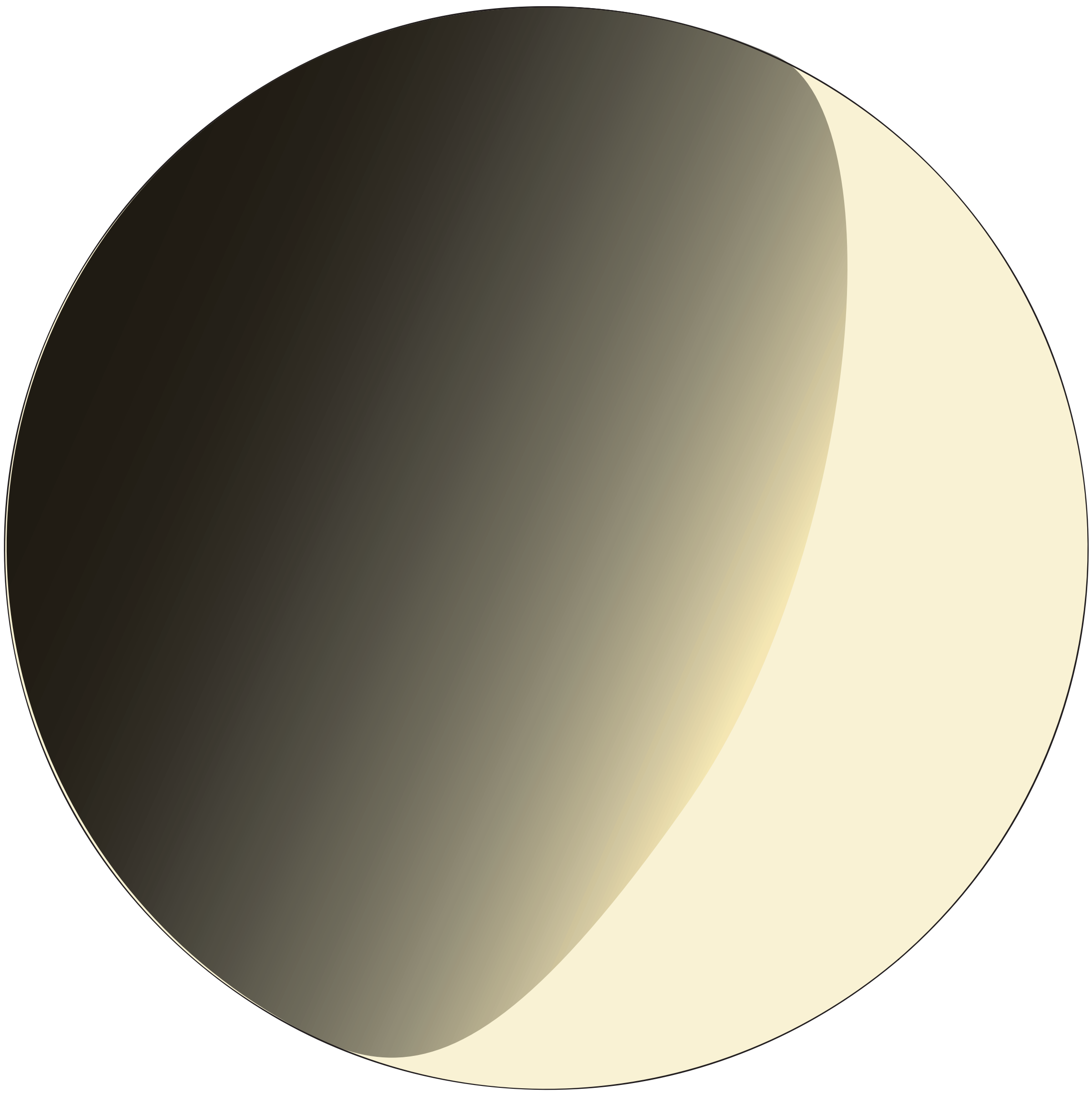
Student Handout

Planet Templates



STUDENT HANDOUT

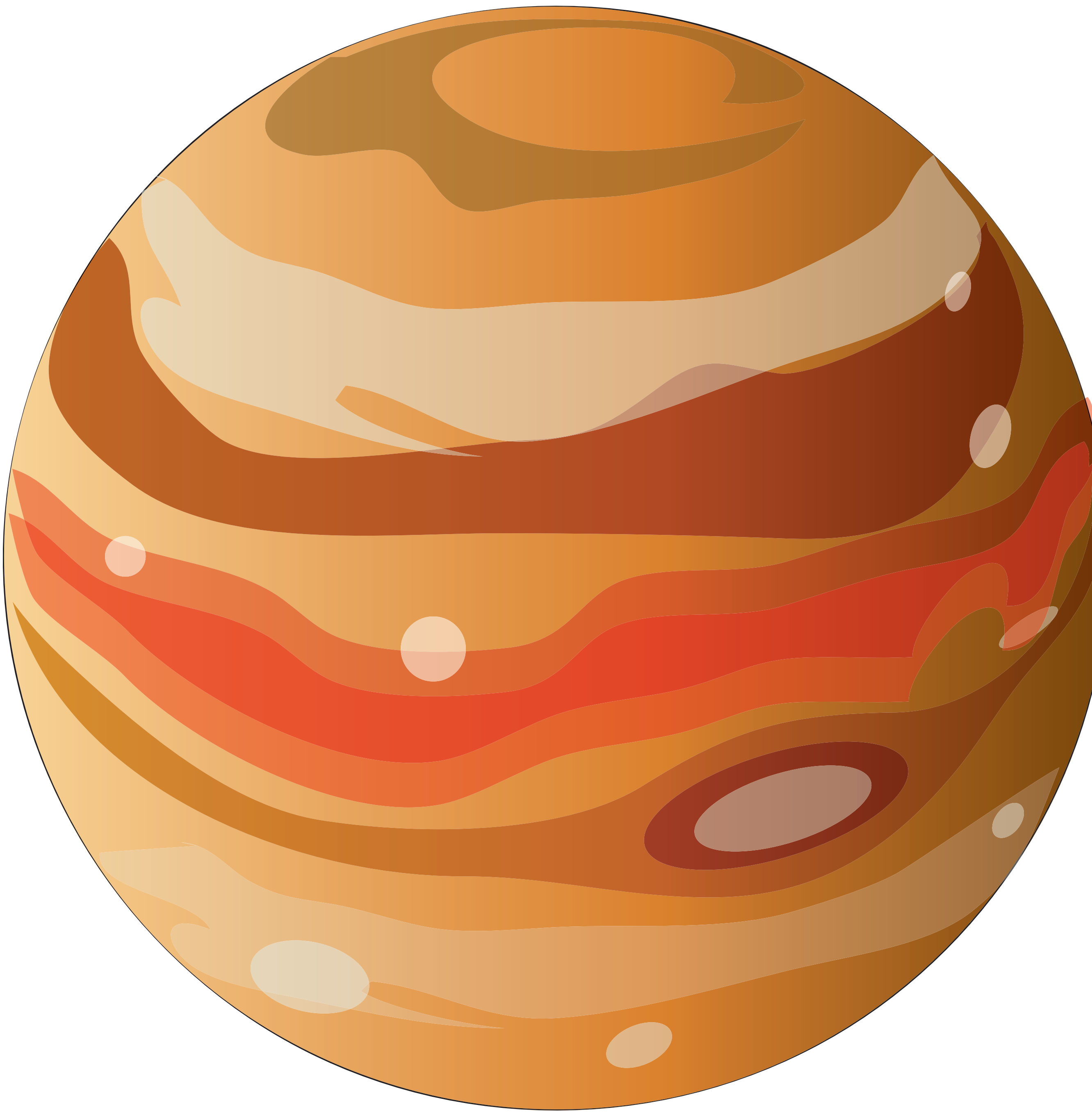
Planet Templates



Saturn

STUDENT HANDOUT

Planet Templates



Jupiter

Teacher Handout

Scale Model Chart: ANSWER KEY

Planets	Actual Diameter (km)*	Actual Distance to the Sun (km)*	Distance to the Sun (tp sheets)	Distance to the Sun (AU)
Mercury	4,879	57,909,175	1.9	0.4
Venus	12,104	108,208,930	3.6	0.7
Earth	12,756	149,597,890 (~93 million miles)	5.0	1.0
Mars	6,794	227,936,640	7.6	1.5
Jupiter	142,984	778,412,010	25.9	5.2
Saturn	120,536	1,426,725,400	47.4	9.5
Uranus	51,118	2,870,972,200	95.4	19.1
Neptune	49,528	4,498,252,900	149.4	29.9
Pluto	2,360	5,905,376,200	196.2	39.2

* Actual planet data used from NASA JPL web site:
http://sse.jpl.nasa.gov/planets/index.cfm

Solar System Model Scale: 1 tp sheet = 30,102,900 kkm

1 tp sheet = 10.16 cm (4 in.)

Teacher Handout

Student Discussion : ANSWER KEY

In the chart below, the following figures in bold are the answers to questions 3 and 4 in the student discussion (See **EXPLORE**)

PLANETS	Actual Diameter (km)*	Diameter (cm)*	Actual Distance to the Sun (km)*	Distance to the Sun (tp sheets)	**Distance to the Sun (cm)***	Distance to the Sun (AU)
Mercury	4,879	.0016	57,909,175	1.9	**19.3**	0.4
Venus	12,104	.0041	108,208,930	3.6	**36.6**	0.7
Earth	12,756	.0043	149,597,890 (~93 million miles)	5.0	**50.8**	1.0
Mars	6,794	.0023	227,936,640	7.6	**77.2**	1.5
Jupiter	142,984	**.0483**	778,412,010	25.9	**263.1**	5.2
Saturn	120,536	.0407	1,426,725,400	47.4	**481.6**	9.5
Uranus	51,118	.0173	2,870,972,200	95.4	**969.3**	19.1
Neptune	49,528	.0167	4,498,252,900	149.4	**1517.9**	29.9
Pluto	2,360	.0008	5,905,376,200	196.2	**1993.4**	39.2

* Solar System Model Scale: 1 tp sheet = 30,102,900 km

1 tp sheet = 10.16 cm (4 in.)

Resources

BOOKS

Maor, Eli: June 8, 2004 – *Venus in Transit*. Princeton University Press, 2000.

Michael Maunder and Patrick Moore: *Transit – When Planets Cross the Sun*, Practical Astronomy. Springer, Berlin, 1999.

WEB SITES

http://sunearth.gsfc.nasa.gov/

http://www.jpl.nasa.gov/solar_system/

http://www.exploratorium.edu/ronh/solar_system

http://www.solarsystem.org.uk/model2.html

http://www.voyageonline.org/

www.eso.org/outreach/eduoff/vt-2004/

www.venus-transit.de/

http://www.imcce.fr/vt2004/

http://didaktik.physik.uni-essen.de/~backhaus
/VenusProject.htm

Figure This!
Offers mathematics challenges that middle school students can do at home with their families to emphasize the importance of a high-quality mathematics education for all.
http://www.figurethis.org

Engineer Girl
Part of the National Academy of Engineering's Celebration of Women in the Engineering project. The project brings national attention to the opportunity that engineering represents to people of all ages, but particularly to women and girls.
http://www.engineergirl.org

NCTM (National Council of the Teachers of Mathematics)
http://www.nctm.org