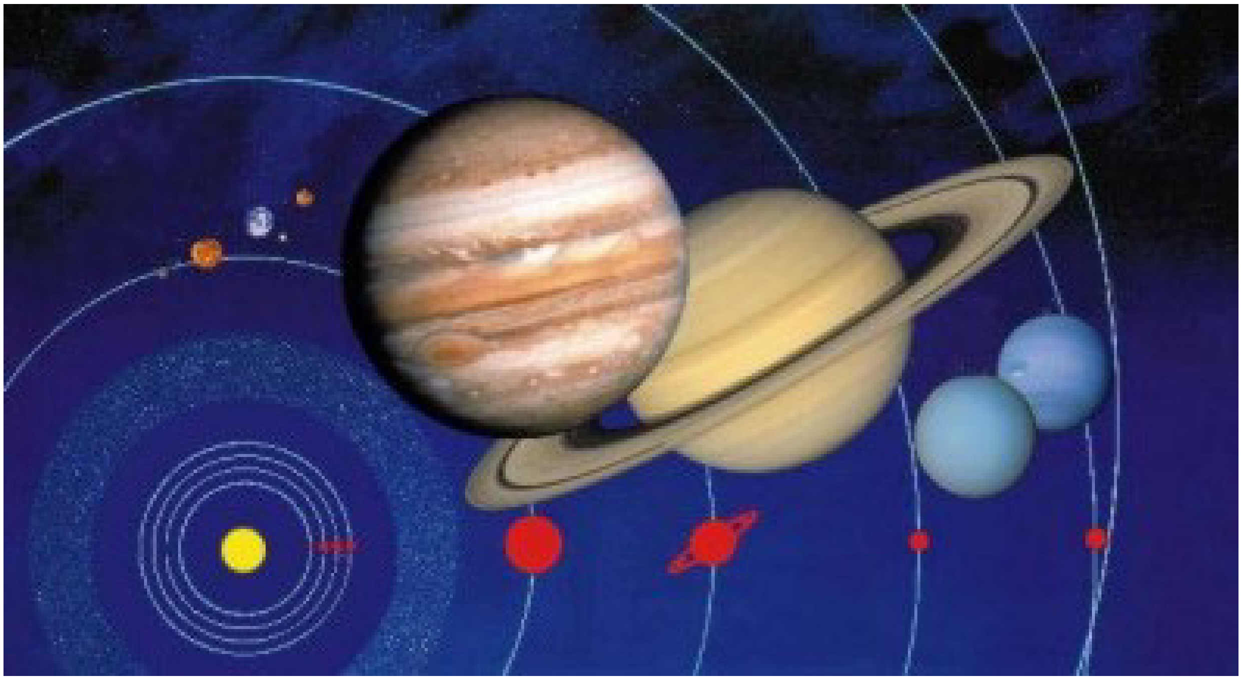
Modeling the Solar System



About These Lessons:

This series of lessons for science and mathematics classes (grades 3-12) looks at the planets in our solar system in a variety of different ways, beginning with astronomical modeling of orbits and sizes, then geologic modeling of planetary interiors, and concluding with biological evaluation of what makes planets livable by various creatures. While the first two are familiar classroom activities, the latter two are new approaches to our solar system that provide new insights. Most of the lessons are presented at two grade levels, basically 3-8 and 8-12. This is based mainly on student mathematics training. Most lessons need multiplication and division, but some use algebra and geometry as real world applications for high school math teachers.

1) Modeling Orbits in the Solar System. This lesson models the orbital distances between the planets and shows that the solar system is mostly empty space.
2) Modeling Sizes of Planets. This lesson compares the relative sizes of the planets to those of familiar fruits and vegetables. It also uses size to calculate density and planet composition.
3) Looking Inside Planets. This lesson involves modeling the interior structures of the planets and shows that the solid cores of the gas giants are similar in size to the Earth or Venus.
4) Search for A Habitable Planet. This lesson looks at the characteristics of planets that make them livable, their temperature, and compositions of atmosphere and surface instead of size or orbit.

Resources: The following resources are available free or at low cost from NASA or some of its partners in planetary exploration and education.

Products:

Solar System Exploration Timeline 2003-2006 is a mini-poster showing solar system exploration mission events in the near future. It is available at http://solarsystem.nasa.gov

Solar System Litho Set consists of 15 photos of solar system bodies with information on the back sides (EP-1997-11-371-HQ). It is available free from NASA Educator Resource Centers or at http://spacelink.nasa.gov/Instructional Materials/NASA Educational Products/Solar System Litho Set/

StarDate Guide to the Solar System is a booklet available from University of Texas McDonald Observatory or online at http://stardate.utexas.edu

Spacecraft Tour of the Solar System or Solar System in 3D slide sets/CD-ROM are available from the Lunar and Planetary Institute or at http://www.lpi.usra.edu/

Web Sites:

Solar System Exploration is the official web site of NASA's Solar System Exploration Division. Its education page has resources and information for teachers at http://solarsystem.nasa.gov

Planetary Photojournal is the NASA JPL compilation of solar system images found on the web at http://photojournal.jpl.nasa.gov/

Welcome to the Planets CD and web site from the NASA JPL Planetary Data System may be viewed on the web at http://pds.jpl.nasa.gov/planets/

Starchild CD and web site from the NASA GSFC Laboratory for High Energy Astrophysics has a section on the solar system which may be viewed at http://starchild.gsfc.nasa.gov

Amazing Space is an educational web site from the Hubble Space Telescope Science Institute that is available at http://amazing-space.stsci.edu/

Lesson 1: Modeling Orbits in the Solar System

Diagram of orbits using an accurate distance scale. [ORBITS]

Objective: Students will construct a distance scale model of solar system in a long hallway or playing field and observe that the solar system is mostly empty space. They will also observe that outer planets are much farther apart than inner planets and learn that it takes a long time to travel through the solar system.

Background:

Our solar system is made up of the Sun, nine planets, about 56 moons, and numerous asteroids and comets. Most of the mass of the solar system is concentrated in the Sun, which is a medium-sized star. (Jupiter, the largest planet, has a mass just 1/100 that of the Sun.) However, most of the volume of the solar system is just empty space. The planets orbit the Sun at distances that are thousands of times larger than their planetary diameters. It is thus difficult to make models that show both distances between and sizes of the planets together. Among the smaller bodies, moons orbit each of the planets except Mercury and Venus, while tiny asteroids and comets orbit the Sun in elliptical orbits.

Materials:

Photos or lithographs (see resources) of the Sun and planets to use in class presentations
Slides, CD, video, or books on the solar system for resources
Solar System Data table
Ball of string knotted every meter (m) for measuring distances

Procedure:

<u>Teacher preparation</u>: Collect materials and prepare 40-50 m knotted string for measuring. Select a location to lay out your solar system. This can be a hallway, gym or athletic field, but for the 1 m scale needs to be 40 m long (approximately 40 yards).

<u>Classroom procedure:</u>

1) Divide class into 9 groups and assign one planet per group Distribute photographs of the planets. Have students read information about their planet and prepare a short report on its important features.
2) Each group calculates the distance of their planet from the Sun in AU (AU=astronomical unit= Earth distance) based on data in table.
3) Set up Sun photo at the designated "central point".
4) Each group measures distance from Sun to their planet with knotted string (scale is 1 AU=1 m) and marks the location with chalk if indoors or a stick/stone if outdoors. Hold photo above mark.
5) Students will now present their planets to the class. Walk with the students through the solar system from the Sun to Pluto. At each planet have the students report what they learned about their planet and answer questions.
6) Discuss distances in solar system and empty space. Have students stand at each planet and wave. Have students guess the size of Sun at this scale (marble).

7) Illustrate time required for space travel.

a) For younger students, gather at Earth and walk from Earth to Mars (that took Viking 1 year); walk from Earth to Jupiter (that took Voyager 2 years); walk from Earth to Neptune (that took Voyager 12 years).

b) For older students, assume that the spacecraft is traveling 65,000 km/hr. Calculate the time it takes to travel from Earth to Mars, Jupiter, and Neptune. Why are these calculated times not the same as the actual spacecraft times? [The planets are moving in near-circular orbits as the spacecraft travels between them. The spacecraft's path, or trajectory, is not a straight line, but a complex curve, and its speed is sometimes boosted by a "gravity assist" as it passes another planet.]

<u>Extensions:</u>

Add Sun, Moon, asteroids and comets to the solar system. Moon orbits Earth at 1 AU - asteroids are in asteroid belt at 2.2-3.3 AU and comets travel on highly elliptical orbits from beyond Pluto to near the Sun.

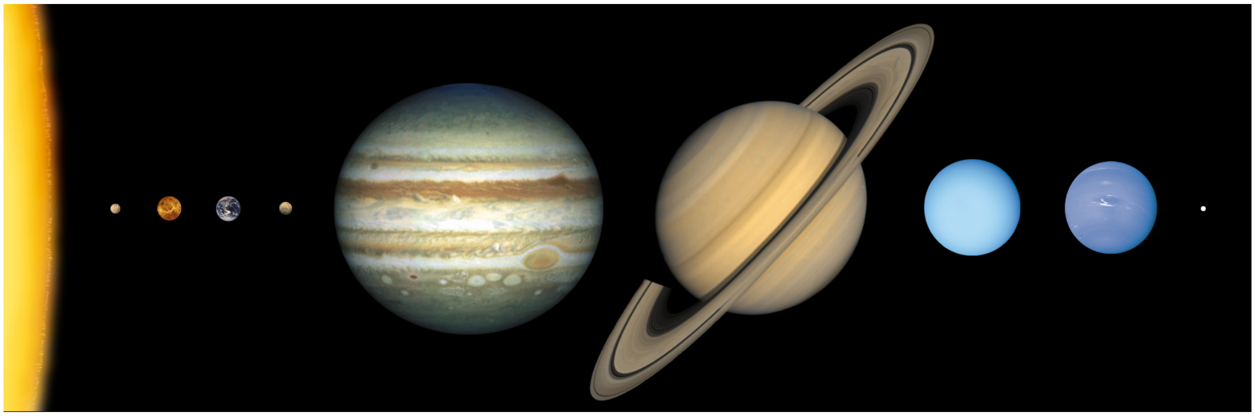
Optional addition is to show slides or a video about the solar system either before or after the activity.

<u>Special Case</u>: *Modeling the Solar System in Space Center Houston* (JSC's visitor center) The central plaza of Space Center Houston is a large black-floored circle that extends down a corridor to the tram line for tours around JSC. When the scale in this activity is doubled to 1 AU=2m, the solar system model fits nicely in Space Center Houston. With the Sun a shooter marble at the center of the plaza, Jupiter is still in the central circle, and Pluto is just outside the door to the tram, 80 m from the center of the "solar system". Students presenting their reports on the planets can interact with visitors to the center as they learn about solar system exploration.

Solar System Data

Planet	Orbit M km	Orbit-AU	Orbit-Year	Diameter K km	Mass 10x24 kg	Gravity	Density	Moons	Rings
Sun	0	0	0	1390	2,000,000	28	7.6	9	0
Mercury	57.9	0.39	88 d	4.88	0.33	0.38	5.41	0	0
Venus	108	0.72	225 d	12.1	4.9	0.91	5.25	0	0
Earth	150	1.0	365 d	12.76	6.0	1	5.52	1	0
Moon	0.38	1.0	28 d	3.48	0.074	0.17	3.3	0	0
Mars	228	1.52	687 d	6.79	0.64	0.38	3.9	2	0
Jupiter	778	5.2	11.9 y	143.0	1900	2.53	1.3	58	1
Saturn	1425	9.52	29.5 y	120.5	570	1.14	0.7	30	8
Uranus	2870	19.2	84 y	51.1	87	0.9	1.3	21	11
Neptune	4490	30	165 y	49.5	100	1.14	1.7	8	4
Pluto	5910	39.5	248 y	2.35	0.013	0.08	2	1	0

Lesson 2: Modeling Sizes of Planets



Planets are shown in order and with a true size scale. Distance is not at true scale. Credit LPI.

Objectives: Students will learn the relative sizes and order of the planets while making a scale model of the solar system using common food items. They will calculate weights and/or gravity on planetary surfaces. They will calculate the densities of planets and learn how density relates to the proportions of components that make up the planets.

Background: The planets vary widely in size (both diameter and mass), having diameters from Pluto at1/6 to Jupiter at 11 times Earth's. The four inner planets are small and dense, while the four outer planets are large and low density. Tiny Pluto is unique. Considerations of size, gravity, and density help us to understand differences between planets. The inner planets are made of rock and metal, while the giant planets are made of gas/ice.

Materials:

Solar System Size and Composition table
Food items listed below or substitute others of the same size
(Lettuce, cantaloupe, lemon, lime, sm. radish, mac nut, sm grape, pea, sunflower seed)

Procedure:

<u>Part 1. Modeling the Solar System with Foods</u>
[Adapted from Dr. Larry Lebofsky, Lunar and Planetary Lab, University of Arizona}
<u>Teacher Preparation</u>: Collect food items, substituting as needed and arrange in random order on table. Copy the page of diameters, hiding the food identification.
<u>Classroom Procedure:</u>
1) Look at the list of diameters of planets and other planetary bodies, notice the size relationships. Which is the largest planet? Which is the smallest? Are some planets close to the same size?
2) Look at the food items provided and decide which ones will represent various planets using the list of diameters as needed.

3) Arrange the food items in a line so they are in order from Mercury to Pluto, making sure the appropriate size scale is followed. The Sun is too big to represent at this scale – unless you have a very large pumpkin!

Questions

1) What is the difference between the planets in the inner solar system (Mercury to Mars) and the planets beyond Mars? If you like, speculate about why there is a difference.

   [Answer suggestions: The inner planets (Mercury, Venus, Earth, and Mars) are all small compared to the outer planets (Jupiter, Saturn, Uranus and Neptune). Pluto doesn't fit this scheme and we don't understand very much about it. The inner planets are solid rocky bodies and the outer planets are mostly gasses and ice. This difference reflects conditions when the planets were just forming. In the inner solar system heat and radiation from the young sun removed most of the gasses and ice, leaving behind rocky materials to make planets. Further from the sun the gasses and ice remained and were included in the outer planets.]

2) Which planet is the closest in size to Earth? [Venus]

3) Which planet is close to the size of Earth's moon? [Mercury]

Part 2 Computing relative weight and gravity on planets

Teacher Preparation; Decide whether to calculate weight given relative gravity or to gravity from basic data. Copy and distribute appropriate data sheet.

Classroom procedure

A) For younger students, calculate the weight of a 50 kg (110 lb) person on each of the planets using the relative gravity numbers given in the data table.

B) For older students, calculate the relative gravity of the planets from the equation

$$g_P/g_E = (GM_E/r_E^2)/GM_P/r_P^2) = M_E r_P^2/M_P r_E^2$$

where g = gravity, M = mass, and r = radius of Earth or planet P

Part 3. Modeling Planet Density and Composition

Teacher Preparation: Decide whether you will calculate density and proportions of components or give them to class to make interpretations. Copy and distribute appropriate data sheet.

Classroom Procedure:

A) For younger students, give them planet densities and the data for components in step 2) below. Ask them what are the two major components of each planet. [Earth's density is between rock and metal, so they are the major components. Jupiter is composed of rock and gas/liq/ice.]

B) For older students, calculate density and major components using the equations below.

1) Calculate planet density of each planet using the formula

   D=M/V =mass/volume (in g/cm3) when

   V = 4/3 pi r^3. is volume of a sphere (pi=3.14, r =radius=1/2 diameter)

2) Relate the density to relative amounts of components. Assume that planets are made of 2 of the following: rock (density 3.5); metal (density 8.0); and gas/liquid/ice (density 0.9). Select the appropriate equation and solve using algebra

   D=(3.5)x + 8(1-x) for x = amount of rock, 1-x = amount of metal
   or
   D=(3.5)x + 0.9(1-x) …for x = amount of rock and 1-x = amount of gas/liquid/ice

Questions: Those in [] are brain teasers.

1) Which planets are made of rock and metal? (Mercury, Venus and Earth, with densities > 5)
2) Which bodies are mostly rock (Moon and Mars, densities of 3 - 4).
   [Why is Moon less dense than pure rock? Because it is made of less dense rock, not because it contains ice. The amount of ice at the poles is very small.]
3) Which planets are mostly liquid/ice? (Jupiter, Saturn, Uranus, Neptune, Pluto, with densities <2) [Which body is lower density than pure gas/liquid/ice? Saturn, because it consists of a less dense mixture of fluids than the other giant planets]
4) [Is it really likely that planets are made of just 2 such components? (No, it is an over-simplication in order to calculate the proportions of major components. Consider Earth, which has an metal core, rock mantle and crust and water/ice/air exterior. The thin veneer of water/ice/air is negligible in proportion, but it is what sustains life!]

Teacher Page

Solar System Size and Composition

Planet	Diameter K km	Mass 10x24 kg	Gravity	Weight 50kg	Density g/cm3	Rock	Metal	Gas/Liq/ Ice
Sun	1390	2,000,000	28		7.6			
Mercury	4.88	0.33	0.38	8.5	5.41	0.58	0.42	
Venus	12.1	4.9	0.91	46	5.25	0.61	0.39	
Earth	12.76	6.0	1	50	5.52	0.55	0.45	
Moon	3.48	0.074	0.17	8.5	3.3	0.92*		0.08*
Mars	6.79	0.64	0.38	19	3.9	0.91	0.09	
Jupiter	143.0	1900	2.53	126	1.3	0.15		0.85
Saturn	120.5	570	1.14	57	0.7	**		1.0**
Uranus	51.1	87	0.9	45	1.3	0.0		1.0
Neptune	49.5	100	1.14	57	1.7	0.09		0.91
Pluto	2.35	0.013	0.08	4.0	2	0.42		0.58

* The Moon is actually made of less dense rock and has minimal ice at the poles.
** Saturn is made of less dense gas/liquid/ice than the assumed average for the planets.

Student Page (grades 3-8)

Part 2 Computing relative weights on planets

Calculate the weight of a 50 kg (110 lb) person on each of the planets using the relative gravity numbers given in the data table.

Part 3. Modeling Planet Density and Composition

Given the data below for the densities of planets and their major components, estimate the two major components of each planet. [Earth's density is between rock and metal, so they are the major components.]

Densities of components are rock=3.5; metal =8; gas/liquid/ice=0.9

Solar System Size and Composition

Planet	Diameter K km	Mass 10x24 kg	Gravity	Weight 50kg	Density g/cm3	Rock	Metal	Gas/Liq/ Ice
Mercury	4.88	0.33	0.38		5.41			
Venus	12.1	4.9	0.91		5.25			
Earth	12.76	6.0	1	50	5.52			
Moon	3.48	0.074	0.17		3.3			
Mars	6.79	0.64	0.38		3.9			
Jupiter	143.0	1900	2.53		1.3			
Saturn	120.5	570	1.14		0.7			
Uranus	51.1	87	0.9		1.3			
Neptune	49.5	100	1.14		1.7			
Pluto	2.35	0.013	0.08		2			

Student Page (grades 8-12)

Part 2 Computing gravity and relative weights on planets

A) Calculate the relative gravity of the planets using the data table and the equation

$g_P/g_E = (GM_E/r_E^2)/GM_P/r_P^2) = M_E r_P^2/M_P r_E^2$

where g = gravity, M = mass, and r = radius of Earth or planet P

B) Calculate the weight of a 50 kg (110 lb) person on each planet using the relative gravities.

Part 3. Modeling Planet Density and Composition

A) Calculate planet density of each planet using the formula

D=M/V =mass/volume (in g/cm3) when

$V = 4/3 \pi r^3$. *is volume of a sphere (pi=3.14, r =radius=1/2 diameter)*

B) Relate the density of planets to relative amounts of components. Assume that planets are made of only two of the following:

rock (density 3.5); metal (density 8.0); and gas/liquid/ice (density 0.9).

Mercury	5.4	Jupiter	1.3
Venus	5.25	Saturn	0.7
Earth	5.5	Uranus	1.3
Moon	3.3	Neptune	1.7
Mars	3.9	Pluto	2.0

Select the appropriate equation and solve for the amounts of components using algebra

D=(3.5)x + 8(1-x) *for x = amount of rock, 1-x = amount of metal*
or
D=(3.5)x + 0.9(1-x) …for x = amount of rock and 1-x = amount of gas/liquid/ice

Solar System Size and Composition

Planet	Diameter K km	Mass 10x24 kg	Gravity	Weight 50kg	Density g/cm3	Rock	Metal	Gas/Liq/ Ice
Mercury	4.88	0.33			5.41			
Venus	12.1	4.9			5.25			
Earth	12.76	6.0	1	50	5.52			
Moon	3.48	0.074			3.3			
Mars	6.79	0.64			3.9			
Jupiter	143.0	1900			1.3			
Saturn	120.5	570			0.7			
Uranus	51.1	87			1.3			
Neptune	49.5	100			1.7			
Pluto	2.35	0.013			2			

Lesson 3: Looking Inside Planets

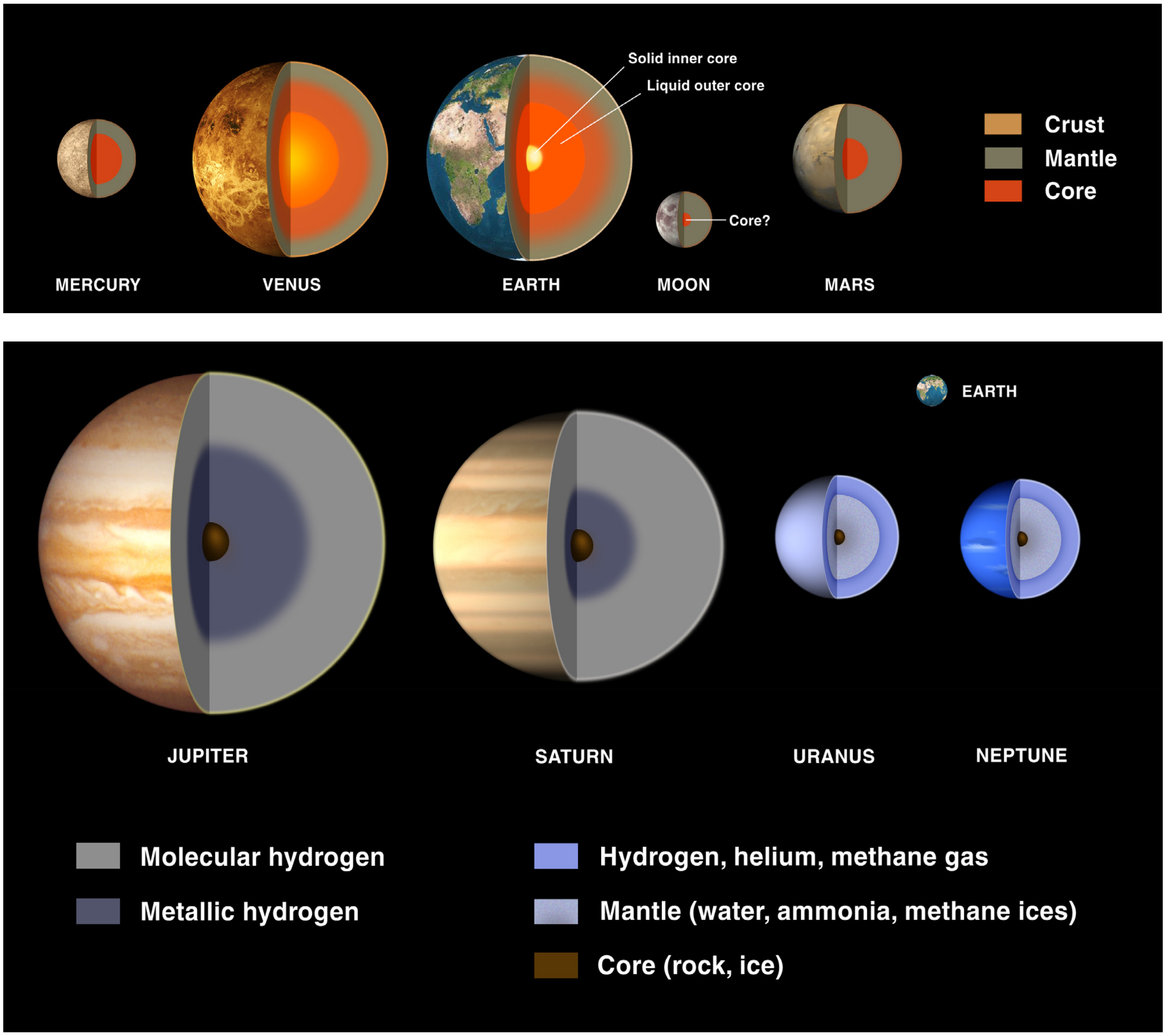


Figure 3. Top - Interiors and compositions of the terrestrial planets and the Moon. Bottom - Interiors and compositions of the giant planets. The two drawings are at different size scales as seen from the size of Earth on the bottom figure. Neither figure represents an accurate distance scale. Credit LPI.

Objective: Students will make scale models of the interiors of the nine planets and compare them. They will see that the structures of the four inner planets are similar to each other, as the structures of the four giant planets. They will discover that the giant planets have rocky cores that are similar in size to the Earth and Venus.

Background:

The planets are divided into the inner planets which are small and rocky, the outer planets which are large and gaseous, and Pluto which is the smallest, most distant, and anomalous. Comparisons within the groups of four inner terrestrial planets or four outer gas giants show strong similarities in composition and internal structure within each group and very strong contrasts with the other group. However, it is fascinating to note that the inner rocky cores of Jupiter and Saturn are near to the sizes of the Earth and Venus. These differences are caused by variations in temperature and gravity during the formation of the planets.

Materials:

for each group

Planetary Interior Data table	art materials to glue on board
poster board, white	cotton balls (atmosphere)
ruler	small bubble wrap (ice/liquid)
compass or pencil on string	sand or sandpaper (rock)
colored pencils or markers OR	Al foil (metal)

Procedure:

<u>Teacher Preparation</u>: Decide whether to use colors or art materials to represent different layers inside planets. Collect materials.

<u>Classroom Procedure</u>:

1) Divide the class into 6 to 10 groups. Distribute Planet Interiors data table and assign each group a planet to model. If there are 6-8 groups, omit planets having others of like size (Venus, Saturn, Neptune). For 10 groups, add the Moon. Gather materials.
2) Using a scale of 1 cm = 1000 km, draw a circle on the poster board with a radius the size of the planet. This represents the planet's surface. For the smaller planets use a compass. For the giant planets use the pencil on a string. Jupiter and Saturn are too big to fit on the poster board. Draw ¼ Jupiter and ½ Saturn.
3) Draw an inner circle with a radius the size of the core and another circle for the interior.
4) Draw an outer circle with a width the size of the atmosphere (0-2 cm).
5) Fill in the circles with colors or glued art materials to represent the composition and state of the layers.
6) Line up the planet models in astronomical order so that students may compare them. Have students describe the size, internal layers, and composition of their planets.
7) Conduct a discussion that compares the inner planets with the outer planets and reasons for variations in size and composition. Consider distance from the sun and likely temperature differences.

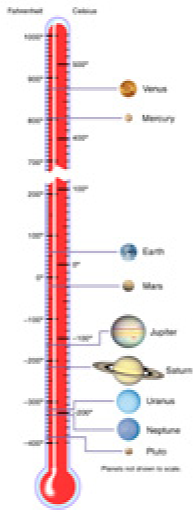
Planetary Interiors Data

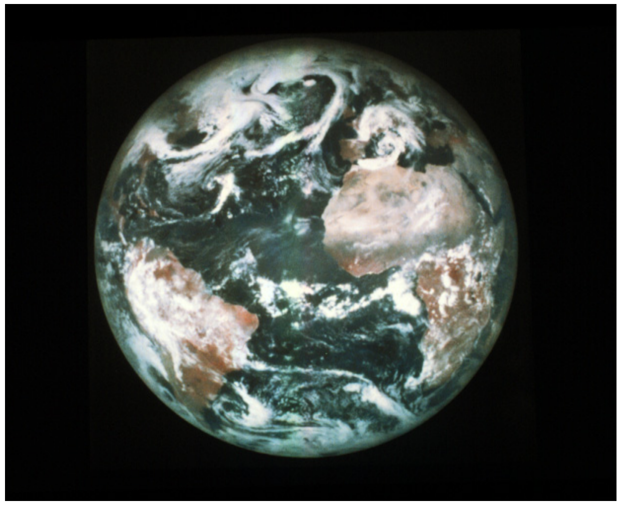
(radii in K km)

Planet	Atmosphere Radius	Atmosphere Composition	Surface Radius	Surface Composition	Interior Radius	Interior Composition	Core Radius	Core Composition
Mercury		none	2.44	rock	??	rock	1.7	metallic iron
Venus	6.5	gas carbon dioxide	6.1	rock	6.0	rock	3.0	metallic iron
Earth	7.4	gas nitrogen, oxygen	6.4	rock (water)	6.3	rock	3.5	metallic iron
Mars	3.6	gas carbon dioxide	3.4	rock (ice)	3.3	rock	1.7	metallic iron
Jupiter	71.8	gas hydrogen, helium	71.5	gas-liquid hydrogen, helium	70/55	metallic hydrogen	15.0	rock, ice*
Saturn	60.6	gas hydrogen, helium	60.3	gas-liquid hydrogen, helium	50/30	metallic hydrogen	16.0	rock, ice*
Uranus	27.2	gas hydrogen, helium	25.5	liquid hydrogen, helium, methane	18	ice water, meth-ane, ammonia	1.0	rock*
Neptune	25.2	gas hydrogen, helium	24.7	liquid hydrogen, helium, methane	19	ice water, meth-ane, ammonia	1.0	rock*
Pluto		none	1.17	Rock, methane ice	??	rock		??

* The deep interiors of the 4 giant planets are very similar in composition and diameter, consisting of 15-19 K km of rock and ice, most likely with more rock in the core and more ice farther out. The compositions of the near-mid interiors differ significantly due to size and pressure.

LESSON 4: SEARCH FOR A HABITABLE PLANET





Objective:

Students will define the life requirements of a variety of creatures and learn that these relate to measurable characteristics of planets the creatures might inhabit. By evaluating these characteristics, students discover that Earth is the only natural home for us in our solar system and that Mars is the next most likely home for life as we know it.

National Education Standards

ESS-Objects in the Sky (K-4), Earth in the Solar System (5-8)
Life-Characteristics (K-4), Requirements, Environment (5-8)

About This Lesson:

This lesson has students take the places of extraterrestrial creatures exploring our solar system in search of new homes. They define creature life requirements and relate them to planet characteristics in order to choose homes. Several of these creatures have life requirements quite unlike life as we know it, where water and carbon are essential, and some are downright impossible. The goals here are not to study biochemistry, but habitability of planets. Bizarre creatures had to be invented for them to find homes on some of the planets in our solar system. Another goal is to encourage creativity and teamwork in designing creatures and selecting planets. This activity is one that is outside of the box.

Both elementary and secondary students can do this activity with slight modifications in the complexity of the data. Do not teach life requirements or planet characteristics as vocabulary, just answer students' questions as they arise and let younger students play a matching game.

Background:

This lesson focuses on characteristics of planets that make them habitable. Living creatures need food to eat, gas to breathe, and a surface that provides a comfortable temperature, gravity, and place to move around. These requirements are related to what the planet's surface and atmosphere are made of, and how large (gravity) and close to the Sun (temperature) the planet is located. The inner planets are small (low gravity), relatively warm, and made of solid rock. Some of them have atmospheres. The outer planets are large (high gravity), cold, and made of gaseous and liquid hydrogen and helium. A creature that might be comfortable on a gas giant would not be comfortable on a small rocky planet and vise versa.

Vocabulary: habitable, life requirements, planet characteristics, surface and atmospheric composition (chemical examples)

Time Required: One to two 45 minute class periods

Materials:

Creature Cards
Solar System Images and Script
Planet Characteristics Table

Art supplies (Styrofoam shapes, pantyhose eggs, Al foil, toothpicks, cotton balls, bubble wrap, wiggly eyes, buttons, beads, pipe cleaners, straws, paper, markers, glue, scissors)

Procedure:

Activity 1. Define Habitability and Design Creatures

1. Set the stage by reading introduction:

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

First we need to know what makes a planet habitable so we can set up probes to measure the characteristics of various planets. The different requirements for life can be related to measurable planetary characteristics. What do creatures require to live?

2. Brainstorm on requirements and characteristics. Lead the students in producing a table similar to the one below. Encourage free-thinking, there aren't specific right answers, but lead students to the following topics, among others.

Life requirements	**Planet characteristics**
food to eat	surface & atmosphere composition

gas to breathe	atmosphere composition
comfortable temperature	temperature range
ability to move	surface type (solid, liquid, gas)
gravity	size

3. Ask students what kinds of probes might be used to measure these characteristics. Answers may range from general to specific and may be based on science fiction. Examples may include cameras, radar, thermometers, and devises to measure magnetics, altitude, and light in all wavelengths from radio waves, through infrared, ultraviolet, and X-ray to gamma-ray. [Secondary school classes might do one of the excellent activities on the electromagnetic spectrum or activities related to solar system missions.]

4. Divide students into six or more teams (more than one group can design the same creature). Explain that each team represents one of the six different types of creatures on our mission. Today we will make models of creatures having specific life requirements. Later we will collect data on a new planetary system in order to search for new homes.

5. Distribute one creature card to each team. Each card contains the information on a single line A-F below. Tell students that each team is supposed to create a creature that fits the characteristics on their creature card. Students may select art supplies (or drawing supplies) and should be able to complete their creatures in approximately 15-20 minutes. Students will name their creature ambassador and be ready to introduce it to the class. Encourage teamwork and creativity!

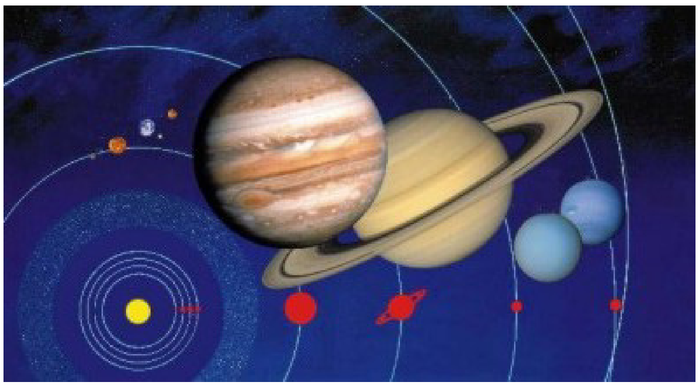
[Teacher, you may get questions on some of the food or gases. Handle these as they come, but do not provide this vocabulary ahead of time unless it comes up during brainstorming. Simply explain that they are various chemical elements or compounds. They are needed only for matching with planetary characteristics and should not be tested vocabulary.]

Creature	Food	Breathes	Motion	Temperature
A	**helium**	**hydrogen**	**flies**	**cold**
B	**rock**	**carbon dioxide**	**flies**	**hot**
C	**carbon**	**oxygen**	**walks**	**moderate**
D	methane	hydrogen	swims	cold
E	**water**	**carbon dioxide**	**walks**	**moderate**
F	carbon	oxygen	swims	moderate

6. Ask each team to introduce their creature ambassador and to explain their creature's needs and any specific features of the model. This will take longer than you expect because students really get involved with their creatures.

Assessment: Evaluate team presentations and collect descriptions of how their creature meets its life requirements.

Activity 2. Tour solar system and evaluate for habitability



1. Prepare students for solar system tour. Tell students that they will have to take notes on the planets to report back later. Students will work in the same teams as when they made creatures. The grade level/ability will determine how the teacher structures the information gathering. Each team may record the information on all planets or on just one or two planets. Young students may simply compare planet characteristics to those on their creature cards and check off boxes of matching characteristics on the planet chart.

2. Distribute copies of the blank planet characteristics chart or put it on the blackboard/overhead. Show slides/photos of the planets and read the text provided below. For elementary students, exclude the data in parentheses. For secondary students, include the data. As you tour the planets, it may be necessary to repeat each section twice for younger students to get enough information to report.

3. Compile information on overhead or blackboard planet characteristics chart as teams report data they recorded on planet (size, surface type, composition, atmosphere and temperature). Attached table gives suggested answers. Students will probably be able to name the planets, but this is not a test. Alternatively, each student could fill in a chart to allow evaluation of listening skills. Also, students could work cooperatively to complete one chart per team.

4. Have teams compare the characteristics chart on the planets with the creature requirements on their creature card. Decide which planets (if any) would be suitable homes for their creature. Report their choices orally and explain, if necessary. Tabulate on the blackboard.

Creature	Planet(s)
A	4,5 (Saturn and Jupiter), but also 2,3 (Neptune and Uranus)
B	8 (Venus)
C, F	7 (Earth)
D	2,3 (Neptune and Uranus)
E	6 (Mars)

No creatures can live on planets 1 or 9 (Mercury or Pluto) because there is not enough gas to breathe.

5. Ask students to create a finale or read the finale below.

Now that the creatures have evaluated habitable planets we will send down spaceships to check out the surfaces in detail. Creatures A, B, D and E find uninhabited planets that are just suited to their needs. They decide to settle on their chosen planets. Creatures C and F are both interested in the same planet. Creature F finds the salt water to be a perfect home for it, while creature C finds the land to be overpopulated and polluted. They decide that there isn't room for one billion more inhabitants and decide to look for a habitable planet in another solar system.

Optional Extensions:

<u>Writing assignment:</u> Ask students to write a paragraph explaining why the planet they found will or will not be suitable for their creature. The paragraph could be in the form of a news report to be sent back to their dying solar system.

Assessment: Collect Planet Characteristics tables and compare with the suggested answers above. Do not require a perfect match, but allow students to think critically and creatively. Allow adaptations of the environment (such as turning water into hydrogen and oxygen) and other reasonable modifications.

Creature Cards

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

Creature A

Food	Helium
Breathes	Hydrogen
Motion	Flies
Temperature	Cold

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

Creature B

Food	Rock
Breathes	Carbon Dioxide
Motion	Flies
Temperature	Hot

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

Creature C

Food	Carbon
Breathes	Oxygen
Motion	Walks
Temperature	Moderate

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

Creature D

Food	Methane
Breathes	Hydrogen
Motion	Swims
Temperature	Cold

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

Creature E

Food	Water
Breathes	Carbon Dioxide
Motion	Walks
Temperature	Moderate

We are space travelers from a distant star system. The crew of our spaceship includes six different types of creatures who live on different planets in that star system. Our star is expanding and getting very hot. Our home planets are heating up and soon we will need new places to live. It is our mission to find habitable planets for our six different types of creatures with different life requirements. In all we need to find new homes for five billion inhabitants.

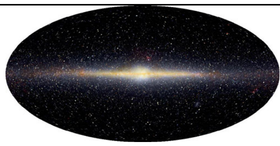
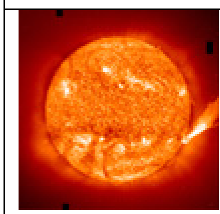
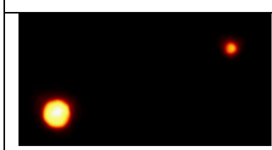
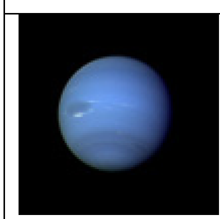
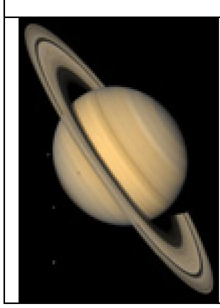
Your task 1) Design a creature that fits the following needs for life. 2) Give it a name. and 3) Introduce it to the class and explain how it meets its needs for life.

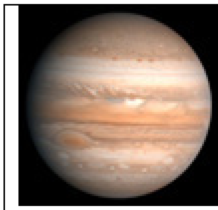
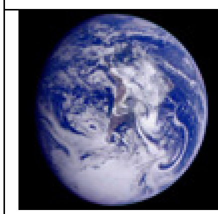
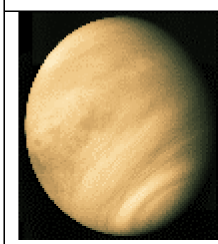
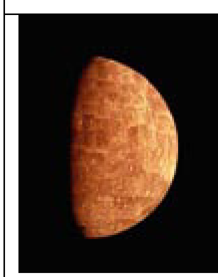
Creature F

Food	Carbon
Breathes	Oxygen
Motion	Swims
Temperature	Cold

Search for a Habitable Planet

Solar System Images and Script

	*Today we are traveling through an outer section of the Milky Way galaxy. There are many, many stars. We are approaching a medium-sized star, the type that often has habitable planets. As we draw closer we see that there are nine planets orbiting this star.*
	*We will tour this planetary system and use our probes to measure planet characteristics in our search for a habitable planet. Record the information about your planet then when we have completed our tour we will collect all our results. We will evaluate our results to look for a new place to live.* *We will now tour this new planetary system, starting from the outside and going toward the star. We are approaching the first planet.*
	*The first planet is tiny (2350 km) and made of rock and methane ice. It has almost no atmosphere (just a trace of methane) and is very cold (-230 C).*
	*The second planet is medium large (49,500 km) and made of liquid hydrogen and helium. It has a thick atmosphere of hydrogen, helium and methane. It is very cold (-220 C).*
	*The third planet is very similar to the 2nd except that it has a small ring system. It is medium large (51,000 km) and made of liquid hydrogen and helium. It also has a thick atmosphere of hydrogen, helium and methane and is very cold (-210 C).*
	*The fourth planet is large (120,500 km) and has an extraordinary ring system. It has no solid surface, but is a giant mass of hydrogen and helium gas outside and liquid hydrogen inside. It is cold (-180 C).*

	*The fifth planet is the largest (143,000 km) in this planetary system. Like the fourth, it is a gas giant made of hydrogen and helium with no solid surface. It is also cold (-150 C) in the upper atmosphere, but increases in temperature and pressure and becomes liquid in the interior.*
	*The sixth planet is small (6786 km) and rocky. There is some water ice in polar regions and a thin atmosphere of carbon dioxide. The temperature is moderate (-23 C).*
	*The seventh planet is medium small (12,750 km). The surface is made of liquid water and rock with some carbon compounds. The atmosphere is mostly nitrogen and oxygen with some carbon dioxide and water vapor. The temperature is moderate (21 C).*
	*The eighth planet is also medium small (12,100 km). The atmosphere of carbon dioxide is so thick that we can't see the rocky surface beneath it, but need our radar probes. The temperature is very hot (480 C).*
	*The ninth planet is tiny (4880 km) and rocky. It has almost no atmosphere (just a hint of helium). Temperatures are generally hot, but extremely variable, ranging from -180 C on the space-facing side to 400 C on the star-facing side.* We have now finished our tour and its time to compile all of our data. Each team will report its results and we will make a comparison chart.

Planet Characteristics
(Teacher key for elementary classes)

Planet	Size	Surface type and Composition	Atmosphere	Temperature	Name
1	tiny	solid rock, methane ice	none	very cold	Pluto
2	medium large	liquid hydrogen, helium	thick hydrogen, helium, methane	very cold	Neptune
3	medium large	liquid hydrogen, helium	thick hydrogen, helium, methane	very cold	Uranus
4	large	liquid hydrogen	thick hydrogen, helium	cold	Saturn
5	very large	liquid hydrogen	thick hydrogen, helium	cold	Jupiter
6	small	solid rock, water ice	thin carbon dioxide	moderate	Mars
7	medium small	solid rock, liquid water, carbon compounds	medium nitrogen, oxygen	moderate	Earth
8	medium small	solid rock	thick carbon dioxide	very hot	Venus
9	tiny	solid rock, methane ice	none (helium)	variable	Mercury

Planet Characteristics

(Teacher key for secondary classes)

Planet	Size	Surface type and composition	Atmosphere	Temperature	Name
1	tiny 2350 km	solid rock, methane ice	none (methane)	very cold -230 C	Pluto
2	medium large 49,500 km	liquid hydrogen, helium	thick hydrogen, helium, methane	very cold -220 C	Neptune
3	medium large 51,100 km	liquid hydrogen, helium	thick hydrogen, helium, methane	very cold -210 C	Uranus
4	large 120,500 km	liquid hydrogen	thick hydrogen, helium	cold -180 C	Saturn
5	very large 143,000 km	liquid hydrogen	thick hydrogen, helium	cold -150 C	Jupiter
6	small 6786 km	solid rock, water ice	thin carbon dioxide	moderate -23 C	Mars
7	medium small 12,756 km	solid rock, liquid water, carbon compounds	medium nitrogen, oxygen	moderate 21 C	Earth
8	medium small 12,100 km	solid rock	thick carbon dioxide	very hot 480 C	Venus
9	tiny 4878 km	solid rock	none (helium)	variable range -180 to 400 C	Mercury

Planet Characteristics

Student Sheet

Planet	Size	Surface type and Composition	Atmosphere	Temperature
1				
2				
3				
4				
5				
6				
7				
8				
9				