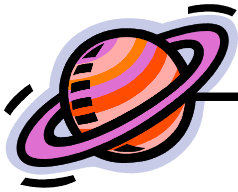


Modeling Sizes of Planets

Middle grades

Lesson Summary

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 a planet's composition.

Prior Knowledge & Skills

- Basic algebra and geometry

AAAS Science Benchmarks

The Physical Setting
The Universe
The Earth
Common Themes
Scale

NSES Science Standards

- **Physical Science**: Properties and changes of properties in matter
- **Earth and Space Science**: Earth in the Solar System

Suggested background reading

Bode's Law
Planetary Physical Data

Teaching Time: One 45-minute period

Materials

Each group needs:
- Solar System Size and Composition table
- Lettuce, cantaloupe, lemon, lime, radish, macadamia nut, small grape, pea, sunflower seed (or food of similar size)

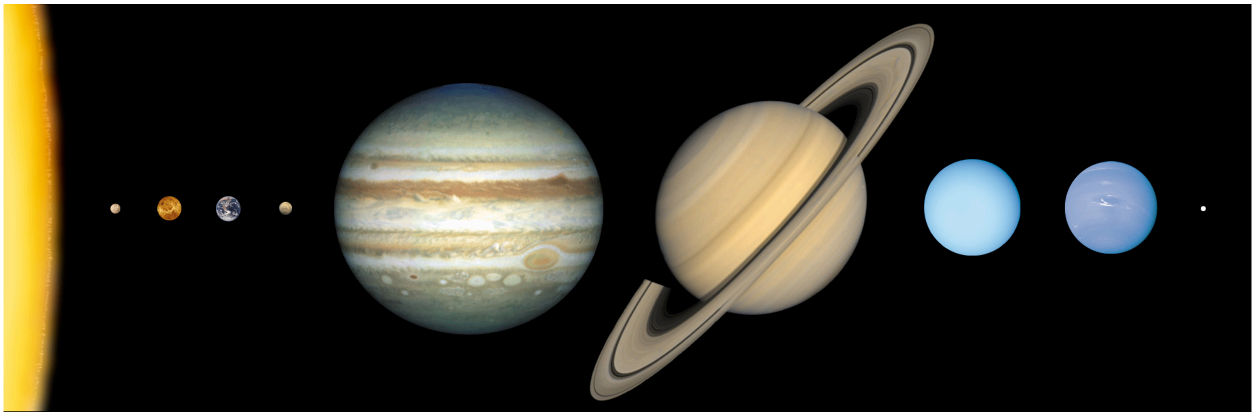
Advanced Planning
Preparation Time: 10 minutes
1. Collect food items and arrange randomly on table
2. Copy Solar System Size and Composition table and appropriate student pages

Science context

This activity gives students some physical intuition about the relative sizes and distances of the planets in our solar system. Students see that the outer planets, especially Jupiter, are huge compared to the inner, rocky planets. Scientists believe this disparity has to do with how the planets formed: in the rotating "protoplanetary disk" of the early solar system, chunks of debris collided with neighboring chunks to form baby planets big enough to attract debris gravitationally. Students also calculate the surface gravity on the planets. Scientists can determine a planet's mass indirectly from its influence on nearby satellites; with that information, they can make an educated guess about the planet's composition.

Source: ARES NASA Johnson Space Center

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:

Part 1. Modeling the Solar System with Foods
[Adapted from Dr. Larry Lebofsky, Lunar and Planetary Lab, University of Arizona}
Teacher Preparation: Collect food items, substituting as needed and arrange in random order on table. Copy the page of diameters, hiding the food identification.
Classroom Procedure:
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			