The Solar System and the Forces Behind It

Summary

Learn why planets stay in orbit. This activity will help make the connection between gravitational force and orbital motion.

Materials

12" piece of PVC tubing (3/8" CTS - 1/2" OD)
1.5 meter of braided nylon string, fused on both ends
One small cork
Various sizes of corks, rubber stoppers, and balls
A piece of large spandex (100% thick, stretchy polyester can work as well)
A variety of balls with various masses and sizes
A bowling bowl or another very heavy ball
A variety of reading material on each planet

- Planetary Summary Chart
- Planetary Summary Chart Answer Key
- Clark Planetarium Solar System 2001 Fact Sheets
- Clark Planetarium Solar System 2002 Fact Sheets
- Clark Planetarium Solar System 2003 Fact Sheets
- Clark Planetarium Solar System 2005 Fact Sheets
- Clark Planetarium Solar System 2006 Fact Sheets

Additional Resources

Books

- *National Geographic Picture Atlas of Our Universe*
  , by Roy A. Gallant ISBN# 0-87044-644-4
- *Exploring the Night Sky*
  , by Terence Dickinson ISBN# 0-90656-66-8
- *Science Encyclopedia with 1,000 Recommended Web Sites*
  , The Usborne Internet-Linked ISBN# 07945-0331-4
- *The Macmillan Book of ASTRONOMY*
  , by Roy A. Gallant ISBN# 0-02-274941-1
- *Journey to the Planets*
  , by Patricia Lauber ISBN# 0-517-59029-8

Gregory L.Vogt - Has a series of books on each planet. Published by Millbrook Press.
Seymour Simon - Has a series of books on each planet. Published by Morrow Junior Books.

Videos

- *Eyewitness - Planets*
  , DK. http://www.dk.com
- *How and Why - Planets and Space Travel*
  , Volume 7. 1-888-661d-8104 www.mediakids.com

Background for Teachers

In Greece, during the third century B.C., Aristotle, one of the greatest 'thinkers' and philosophers of all times decided Earth is the center of all existence and all heavenly bodies revolved around it in perfect circles. On what evidence or observational data did Aristotle base his theory on? None. He thought and thought about it and concluded that was the most logical explanation. However, everyone loved

this idea of a geocentric (Earth-centered) universe. It made everyone feel important.
A Greco-Egyptian astronomer named Claudius Ptolemaeus, known as Ptolemy, refines Aristotle's ideas in the second century A.D. that Earth was the center of the universe. People remained feeling special, happy and content because it's only right that everything should revolve us. Besides, there are references in the Bible that seem to support the idea of geocentricity.

For thousands of years this theory was so widely accepted -- it became accepted truth. It wasn't until the mid 1500's that a Polish astronomer named Nicholas Copernicus challenged the idea of a geocentric system because it did not explain the planetary motions. He developed a theory that Earth and the other planets orbit the Sun and is heliocentric ("Sun-centered"). People were angry at this idea because they lost the center of attention. However, Copernicus never had to deal with the wrath of the general populous because he died right after his ideas and theories were published.

In the early 1600's, an Italian astronomer Galileo Galileo, with his telescope and observations of Jupiter's moons and Venus's phases proved that Copernicus was correct. The Sun is at the center of our system of planets, moons, and all heavenly objects orbit around it. However the public outrage was incredible! Nearly everyone accepted the Church's teachings that the Sun orbits Earth. Even with evidence to support a Sun-centered system, Galileo was put on trial for publishing his 'heretical' observations. Under threat of torture (and Galileo is now quite old these days), renounced his ideas and spent the rest of his life under house arrest.

Our Solar System consists of a star, our Sun, nine orbiting known planets and their moons, asteroids, meteoroids, and comets. Our Sun, like other stars, is a huge ball of burning gases that produces tremendous amounts of heat and light. The Sun contains 99.86 percent of the mass of the entire solar system. Because of its mass, it gravitational force is able to keep the planets and all other objects in our Solar System in their elliptical orbit. Scientists believe that energy from the Sun is transferred through space in waves or magnetic energy known as the electromagnetic spectrum.

Planets are large heavenly bodies that orbit a star, in our case it's the Sun. The word planet comes from the Greek word meaning 'wanderer'. Ancient astronomers did not know how to explain how these moving objects could change their position in the heavens. The planets are at times referred to as the inner planets consisting of Mercury, Venus, Earth, and Mars. Each of these terrestrial ('land') planets have a rocky core and are extremely small in comparison to the giant gas planets. The giant gas planets are known to be the outer planets and are both massive in size, and mostly made of gases with a small solid core. Then there's Pluto. Not necessarily an inner planet, but it is considered another small, terrestrial rocky planet.

Moons are natural satellites that orbit planets. Every planet has at least one moon except the planets Mercury and Venus.

Asteroids! There's tens of thousands of them tumbling and bumping lumps of rock orbiting the Sun. Asteroids are also known as 'minor planets' or 'planetoids' and get their name from the Greek word that means 'starlike'. When seen through a telescope, an asteroid looks like a faint star. There is an enormous gap of space in between the inner planets and the outer planets which consists of the 'Asteroid Belt'. The vast majority of asteroids orbit the Sun between Mars and Jupiter. But they can also inhabit different regions of the solar system. Asteroids range in size from less than one kilometer in diameter to hundreds of km. They are usually irregular in shape and bumpy, not smooth and round like larger planets. Their surface is pockmarked with craters because over time they eventually crashed into one another. They split apart into smaller and smaller fragments leaving dust and smaller asteroids in the Asteroid Belt. Asteroids are made mostly of different types of rock, often rich in iron and other metals, and some ice. Since many meteorites found on Earth contain similar materials, astronomers believe that most meteorites are broken bits and pieces of asteroids that land on Earth.

Meteoroids are fragments from asteroids that have collided and split apart in small bits and pieces. These asteroid collisions send the meteoroids flying off in all directions across the Solar System.

Some zoom toward Earth but the friction from our atmosphere makes the meteoroids so hot that they burn up in our atmosphere making a fiery streak of light called a meteor. People have referred to these 'falling stars' or 'shooting stars'. When a meteoroid survives its hot journey through Earth's atmosphere and falls to the ground, it is called a meteorite.

Comets have been referred to by astronomers as 'dirty snowballs' and 'as close to nothing as something can get' because they seem to be nothing more than rock dust wrapped around a spongy ball of ice. Throughout history there have been many superstitions about comets and many people were terrified calling them 'terrible stars' and 'death-bringing stars'. Other people thought they were a sign of good fortune sent from the gods. Comets are made up of extremely small quantities of very simple chemicals like water, carbon dioxide, ammonia, methane, and space dust. They have a small head, called a nucleus and as it travels in its orbit toward the Sun, it slowly melts and releases space dust and gases. The space dust reflects light from the Sun looking like a giant ponytail in the sky. This is how comets originally got their name, from a Greek word meaning 'longhair'. As a comet nears the Sun, it warms up. Ice evaporates from its surface and forms a large, tenuous cloud called a coma and the gases released form a yellowish dust tail and a bluish gas tail. The tail of a comet can stretch out for millions of kilometers. As the comet loops around the Sun and then speeds away in the same direction of its orbit, its tail is ahead of the comet rather than behind. Coming or going, the comet's tail always points away from the Sun. Astronomers have studied enough comets to be sure that these visitors are members of the Solar System, just very distant members. Comets seem to have 'home ground' in the farthest reaches of the Solar System beyond Pluto. The home ground is a huge region called the Oort Cloud. The gravitational force of a passing star can snatch a comet from the Oort Cloud and fling it into a cigar-shaped elliptical orbit that brings it close to the Sun. Often times, comets will be pulled into Jupiter's gravitational pull and never return to the Oort Cloud. This was the case in 1994, when Comet Shoemaker/Levy 9 rammed into Jupiter. Jupiter's powerful gravity pulled the comet apart, so the planet was pelted by almost two dozen impacts.

A force is needed to cause something to move in a curved path, the planets and all heavenly objects, are no exception to this rule. A force of some kind must be acting to hold them in their orbits around the Sun. Isaac Newton connected this concept with the same force that pulls objects to Earth's surface. Newton theorized that the moon revolves around the Earth. He called this phenomenon gravity and described it as an attractive force between any two objects. The strength of the force is related to the object's mass (which is the amount of material an object contains).

The force of gravity attracts objects to each other. This attraction is not noticeable unless one of the objects is very large, such as a planet. The area within which gravity has an effect is called a 'gravitational field'. The Earth and Moon both have gravitational fields, although the Earth's is many times greater than the Moon's because it is a much bigger object.

The strength of the pull of gravity between two objects also depends on how far apart they are and their masses. Weight is the measure of the pull of gravity on an object's mass. The further away an object is from the center of the Earth, the less pull gravity has on it. Gravity is a fundamental force in the sense that is cannot be explained in terms of any other force. Gravitational forces act between all bodies everywhere and hold planets, their moons, stars, and galaxies together.

Intended Learning Outcomes

1. Use Science Process and Thinking Skills.
3. Understand Science Concepts and Principles.
4. Communicate Effectively Using Science Language and Reasoning.

Instructional Procedures

Invitation to Learn

Why do planets stay in orbit? This activity will help make the connection between gravitational force and orbital motion. Participants will make observations, record discoveries, and graph data as they change different variables: such as, the size and mass of different corks and rubber stoppers, and length of string.

Instructional Procedures

- Thread the string through the PVC pipe, then string through the hole in the cork, rubber stopper, or ball, and tie a knot.
- Hold the PVC pipe handle with the washers at the bottom of the tube and insert the small cork into the pipe to keep the weights at a constant. (Optional extension: The number of washers used at the bottom can become another experiment and variable.)
- Raise handle above your head and begin to rotate so that the object is circling (orbiting).
- Record observations made in Science Journal

Activity #1 -- Oops! There It Goes!

- Discuss the concept of gravity and determine what students know about it.
- Drop a ball and have students explain why it falls downward.
- Ask students questions such as: How does the mass of an object determine the strength of its gravitational pull? How would the effect of a gravitational pull change if both objects had close to the same amount of mass? If one had much more mass than the other? Have students justify their responses and give examples.
- Have four to six students stretch, as taut as they can, using a piece of spandex material. Explain to students that this represents space.
- Give six to eight other students select different size and weights of balls. Roll them across the stretched spandex material and make observations about how and where they move.
- Place a bowling ball (or another heavy round object) in the center of the spandex material and repeat the same procedure with rolling the small balls across 'space'. Have students make observations and discuss the differences.
- Ask questions such as: How is it that when the balls were rolled across the spandex the first time, they went straight? How is it that the balls changed their movement direction after placing the bowling ball in the center? How would changing the bowling ball to a ball with less mass affect the movement of the other balls? A ball with a larger mass than the bowling ball? How does this activity demonstrate gravitational pull? Have students justify they answers with evidence from their observations. Encourage them to give samples of this phenomena.

Activity #2 -- My Very Energetic Mother Just Served Us Nine Pizzas (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto)?

- As a class, make a list of objects found in our solar system.
- Explain that each group of students (there should be 10-12 groups working in pairs or triads) which will focus on one object listed on the board. Each group will then become the 'class expert' on that topic. (Objects that must be covered are the nine known planets, asteroids, meteoroids, and comets.)
- Teacher models questioning techniques on 'wanting to know more' about their topic. Individually, students think and write about (three to five) questions they want answered during the research activity. Each member of the group then shares their questions and they make a group list of their top five questions of what they 'want to know more' about.
- Students will be given specific information and criteria to be included in their presentation. This specific information will be used by the rest of the class to fill in a Planetary Summary Chart.
- Distribute a packet of Clark Planetarium Solar System Fact Sheets to each student. Focus on the following: length of year, length of day, average orbital velocity kph, equatorial diameter in km, surface gravity, temperature extremes in ºC, number of known satellites, and inclination of equator (tilt). Discuss in detail each category and to what it is referring. Make a class chart, using the students own words to describe each category. Have students record this chart in their

Student Journal for future reference.
In a class discussion, use the Clark Planetarium Solar System Fact Sheets to compare data from year to year. What are some categories that stay the same? Which ones have changed? Compare the velocity of a planet to its length of day? Compare the surface gravity of other planets to Earth? Which is the hottest planet? The coldest? Which planet is tilted the most? the least? What happens to a planet's orbit when its tilt is more than 90 degrees?
While doing their readings and research, have students to take note of the date of publication of the resource and reference materials they are using--encourage them to use the most current data available.
Students are then given several resources to read and research to help generate an interest in wanting to know more and essential background knowledge regarding their topic. They are also expected to find and use five additional resources from other sources, with the Internet being one.
After their research work, each member will individually write a one to two page summary of the findings about their topic of expertise. Each group will then collaborate on how they are going to report their findings to the class.
These presentations can be as creative and varied as determined by the group. However, presentations MUST include the specific factual information given to them previously so the class can fill out their Planetary Summary Chart worksheet.
For presentations on meteors, asteroids, and comets, students will use a graphic organizers to record information presented by those groups.
Give 10-15 minutes after each presentation. Students listening to the presentation need to reflect and write in their Science Journals a paragraph about "Something new I learned was . . ."

Extensions

Curriculum Extensions/Adaptations/Integration

Staying Up While Falling Down

This activity demonstrates how a satellite (natural or man-made) stays in orbit by modeling the effects of Earth's gravity on a satellite and the Sun's gravity on the planets. Participants will observe gravity acting as a centripetal "center-seeking" force.

Using a fine grade sanding paper, sand the top end of the PVC pipe smooth. (Do not sand both ends, the rough cut end is needed for the Invitation to Learn activity.)
Thread the string through the PVC pipe and attach the weights (a gravitational force) at the bottom of a the PVC pipe. Remove the small cork stopper.
Place a 'satellite' on the top end of the PVC pipe. Hold the PVC pipe and swing the satellite in orbit, the weight pulls on the string to keep the satellite from flying off. Also make observations of how the weights move up and down.

Note: Gravity and centripetal motions are two different forces. Gravity helps to keep objects in orbit by using centripetal force. (However, centripetal force makes objects go in a circular path rather than elliptical.) If gravity did not exist, objects would keep moving out and eventually fly off into space.

Writing A Persuasive Paper - Is Pluto A Planet?

This writing activity integrates reading comprehension, the writing process, and science skills of logical reasoning and using evidence to support a particular conclusion.

Have students compare different definitions of what makes a planet. As a class, decide what characteristics and components determine whether an object in our Solar System is a planet.
Review with students the nine 'known' planets determine whether or not each fits the class's definition of a planet and justify why. Also review the Asteroid Belt, Kuiper Belt, and the Oort Cloud and their locations within the Solar System.

Pose the question, "Is Pluto A Planet?" Before any other information is given, take an initial class vote on where they stand on this controversial question.

Assessment Plan

Give each student a long black sheet of bulletin board paper measuring five meters by two meters. This represents space in within the Solar System and offers a great way to integrate art with science. *This assessment activity can also use six 8 1/2" x 11" sheets of copy paper taped horizontally together. This would allow them to keep it in their Science Journal.

Give each student two to three pieces of white card stock and a compass and have them draw to scale, each planet using the equator's diameter (Scale: 1 mm = 1 km) Planets will initially be white circles which will then be colored with its proper physical characteristics.

Using a meter stick, set the colored planets in order from the Sun keeping in mind approximately its correct tilt (i.e., Uranus should be placed with its rings almost vertical). Each planet needs to be at the correct distance using the same scale of 1 mm = 1 km, from the Sun.

Above each planet label it with its name. Under each planet, indicate both km and its AU units from the Sun. (*For labeling on black paper, silver pens work great.)

Using colored chalk, add details such as moons and rings, the Asteroid Belt, meteoroids, and comets, the Oort Cloud, etc.

Bibliography

Research Basis

National Research Council (2000). *Inquiry and the National Science Education Standards--A Guide for Teaching and Learning*

"Inquiry-based instruction is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to what is already know; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking and consideration of alternative explanations."

Freedman, R.L.H. (1994). *Open-ended Questionings--A Handbook for Educators*

"Student-centered authentic assessment occurs when critical-thinking skills,, the writing process, and content-area instruction are combined and used in open-ended questions. By their nature, open-ended questions assess writing, conceptual understanding, and thinking skills--especially students' abilities to analyze, to evaluate, and to solve problems."

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