Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2007 Volume III: The Physics, Astronomy and Mathematics of the Solar System

The Physics of the Planets: How 16th and 17th Century Physicists Helped Us Understand Our Solar System

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Objective

Students will learn basic physics concepts and how they apply to the movements of the planets and other objects in our solar system corresponding with the following Science Standards:

> 8.1-Forces and Motion-what makes objects move the way they do?
> 8.3-Earth in the solar system-How does the position of Earth in the solar system affect conditions on our planet?

Introduction

This unit is designed for a class of about 20- 25 eighth grade students that is co-taught by a certified regular education Science teacher and a certified Special Education teacher. About twenty five percent of the students in this class come from surrounding suburban schools where they have had more direct experience with Astronomy due to decreased outdoor lighting. Another twenty five percent live in the inner city neighborhood where the school is located and the remaining students come from other areas of the city.

To introduce students to astronomy the teachers will present brief information about ancient Chinese, Mayan and Egyptian astronomy. Next, students will be organized into groups of four to five to research basic biographical information about a scientist from the 16th and 17th century. Because the class is a mixture of regular education students and students who have special education IEPs, the instructors will set up the groups to consist of students of varying skills and abilities in each. Each group will be assigned one of the three following people to research: Isaac Newton, Tycho Brahe or Johannes Kepler. Eighth graders connect to factual information better when they can relate to it in a personal way so, they will be encouraged to find anecdotal personal information as well as facts about the person's development as a scientist and what he theorized and discovered.

Students will be prompted with suggested websites to use. Research will take place in the school's tech lab since many students do not have Internet access at home. Teachers will work with each group at specific times to be sure that they are finding the necessary facts about each scientist. The research sessions will be interspersed with lessons on basic physics laws presented by teachers. At the culmination of the research each group will present their information to the class. Because the school is an Arts Magnet school the rubric for presenting the scientist will include an artistic component such as visual art, music or theater.

Unit

Ancient Astronomy of the Mayans, Egyptians and Chinese

As astronomers the Maya were quite accomplished. They were interested in Zenial Passages, when the Sun crossed over the Maya latitudes. Each year they accurately predicted the equinoxes and the solstices. They even built a pyramid in which the sun shines through on the equinoxes in the form of a snake slithering up and down the steps. (3, 8)

The Egyptians noticed that the bright star Sirius rose before the sun around the time of the summer solstice shortly before the annual floods of the Nile River. This was important to them because they planted their crops just after the flood. The astronomers who predicted this were priests. They also used astronomy in the positioning the pyramids. They were aligned accurately with the star B Scorpii's rising direction. (3, 7)

In ancient China astronomers developed a complex lunisolar calendar based on the phases of the moon. A great deal of mythology arose from observing the planets and stars. They believed that solar eclipses were caused by a dragon devouring the sun. They also built sophisticated observatory buildings where they, quite accurately, tracked and calculated the movements of the stars. (3, 7)

16th and 17th Century Astronomers

The first group project of the unit will introduce students to three astronomers and mathematicians who have played an essential role in explaining the movement of the planets and, who set the stage for modern astronomy: Tycho Brahe, Johannes Kepler, and Sir Isaac Newton.

Students will learn basic biographical information about the scientists and their work in math and astronomy and how it led to their discoveries of inertia, gravity, circular motion, speed, acceleration, rotation and revolution of the planets.

Tycho Brahe

Tycho Brahe was born in Knutstorp, Skanne, Denmark which is now Svalov, Sweden with a twin brother who died shortly after birth. When he was just two years old his uncle, Jorgen Brahe took him out of his parents home and began raising him as his own son. Oddly enough his parents accepted this; they did not object or try to get him back.

Since his family was wealthy and members of Danish nobility he had excellent opportunities for education and attended school starting at age seven. At age twelve he began attending the University of Copenhagen. While he was there he became especially intrigued by the eclipse which occurred on August 21, 1560. This prompted him to purchase astronomy texts and study independently with some help from his professors even though his uncle originally sent him to study Law.

In 1562 his foster parents sent him to the University of Leipzig to study classical languages like Latin and Greek and to study culture. However, as at Copenhagen, he was more interested in studying astronomy and brought with him his astronomy books and constellation maps. He made observations of the night sky and kept records of these observations. His observation of a conjunction of Jupiter and Saturn became important to his later career because he was more accurate than Ptolemy and Copernicus, two famous astronomers. While being taught by Bartholomew Schultz at Leipzig he learned that quality instruments help to make accurate observations and he began to acquire them.

After his uncle died, his parents resumed responsibility for him. They sent him off to the University in Wittenberg and then to the University in Rostock. Due to a disagreement with another student in Rostock, he became involved in a sword fighting duel. During the fight, part of his nose was cut off. Because his face was now terribly disfigured he wore an artificial nose piece made of gold and silver.

After his father died in 1571, his mother's brother helped him build an observatory in Herrevad Abbey. In 1572 he wanted to marry Kirsten Jorgesdatter, but because he was a noble and she was a commoner they were not allowed to be married legally so they lived together and had a family. That same year he also observed a new star in the constellation of Cassiopeia. The star is now known as "Tycho's supernova."

In 1574 Brahe briefly taught astronomy at the University of Copenhagen, but what he really wanted to do was set up his own observatory. He visited an impressive one in Kassel which influenced the design of his own which he named Uraniborg. It was set up on the island of Hven in Copenhagen Sound. He worked and made observations there for twenty years. At Uraniborg he observed a comet and was able to prove that it was not closer to the Earth than the Moon which contradicted Aristotle's model of the cosmos.

Because Brahe needed more room for his many large instruments he built another observatory named Stjerneborg next to Uraniborg. At his observatory he not only observed stars and planets, he made instruments that were helpful in measuring distances of objects in space and calculating their movements. Brahe's calculations were very precise and few have been proven wrong by modern instruments.

Brahe did however develop an incorrect theory of the solar system. In his early years he believed that all the planets revolved around the sun. He attempted to explain that through observing a parallax shift. However people of that time did not fully grasp the vastness of the universe which would have explained it so, he theorized that all other planets revolved around the sun and that the earth was fixed in space with the sun and the other planets revolving around it.

In 1599 the Holy Roman Emperor, Rudolph II appointed Tycho Brahe to be the Imperial Mathematician in Prague. One of his assistants was Johannes Kepler. It was Brahe's hope that their calculations would prove his theory. Unfortunately he died eleven days later mainly because he was trying to follow the laws of etiquette of the day. Kepler describes his death:

Holding his urine longer than was his habit, Brahe remained seated...he felt less concerned for his health than for etiquette. By the time he returned home he could not urinate any more. Finally, with the most excruciating pain, he barely passed some urine, but yet it was blocked. Uninterrupted insomnia followed: intestinal fever; and little by little delirium....During his last night, through the delirium in which everything was very pleasant, like a composer creating a song. Brahe said these words over and over again: "Let me not seem to have lived in vain."(5.)

Kepler succeeded Brahe as Imperial Mathematician. The accuracy of the many calculations made by Brahe helped Kepler who believed, like Copernicus, that the sun was the center of the universe, to compose his three laws of planetary motion and create astronomical tables, the Rudolphine Tables, which helped in the future to convince other astronomers that Copernicus' theory was correct.

Johannes Kepler

Johannes Kepler was born in Weil der Stadt, Wurttemberg, Holy Roman Empire, which is now Germany, on December 27, 1571. Kepler is known for the three laws of planetary motion which he discovered and were named after him. In addition he made many discoveries and advancements in the field of mathematics. Also notable is the Rudolphine Tables; precise astronomical calculations which accurately prove that the planets, including Earth revolve around the sun.

Kepler was born in a small town and lived at an Inn owned by his grandfather. He last saw his father, who went off to war in the Netherlands and was probably killed, in 1576. As a child he attended a seminary school near his home, and later went to the University of Tubingen with the intention of being a minister. Many of Kepler's writings express his devotion to God and the connection he saw between the design of the universe and religion.

The study of mathematics was emphasized in Kepler's education. When Kepler began school the geocentric theory of the solar system, which means that the sun and all other planets revolve around the earth was most commonly taught. However, his professor, Michael Maestlin, chose to teach him the heliocentric system, which means that all of the planets revolve around the sun. (Ge means earth and helios means sun).

The term "satellite" meaning attendant, used to describe planetary moons was coined by Kepler in 1610 to describe the moons surrounding Jupiter. The term was later used also to describe Earth's moon.

To back up his belief in the heliocentric Copernican system in 1596 Kepler wrote Mysterium Cosmographicum. This included a complex geometrical drawing to describe the positions of the planets and he also explained that mercury and Venus are always seen closest to the Sun because they are between Earth and the Sun. Because of his work on this book he got the attention of Tycho Brahe and obtained the position as his assistant.

Shortly after Brahe's death, Kepler was able, by working with the extensive calculations and models designed by Brahe from his meticulous observations, to conclude that the orbit of Mars was not circular but elliptical. This theory is now applied to all planets and known as Kepler's First Law: the orbit of each planet about the sun is an ellipse with the sun at one focus. This work also led to Kepler's Second Law: as a planet moves around its orbit, it sweeps out equal areas in equal times; which uses the area between a planet and the Sun to measure time. The calculations that Kepler made were so accurate that they match the measurements made with modern instruments of the twenty first century.

In 1611 Kepler developed a new telescope that uses two convex lenses. It is so commonly used that it is now known as the astronomical telescope.

In the next few years Kepler experienced several unforeseen tragedies and difficulties; first, the death of his wife, and his son. Then, his mother was put on trial for witchcraft. His personal and professional connections to royalty and their favoritism toward one religion or another was in turmoil. However, Kepler did not allow these circumstances to disrupt his work. He moved to Linz, Austria remarried and continued to work on The Harmony of the World.

The Harmony of the World was an elaborate work of mathematics and its connection to the cosmos and music theory. What is now known as Kepler's Third Law: orbital period in years squared equals average distance in astronomical units squared; a law that relates the size of a planet's orbit with the time period of its orbit was a part of that work.

While working for Albrecht von Wallenstein Kepler continued to work on The Rudolphine Tables and they were published in 1628 just two years before he died on November 15, 1630. (6.)

Sir Isaac Newton

Isaac Newton was born in Woolsthorpe, Lincolnshire, England on January 4th, 1643 to a wealthy but uneducated family of farmers. He was raised by his grandmother because his father had died before Isaac was born and his mother remarried. His childhood was unhappy and he was unsuccessful in school.

Despite his mother's insistence that Isaac manage her property and money, his uncle, William Ayscough arranged for him to complete school where he lived with the headmaster who took interest in his academic ability, encouraged him, and convinced his mother to allow him to attend the University.

In 1661 Newton enrolled in Trinity College, Cambridge as a sizar, a student who worked for other students in exchange for tuition. This was unusual because his mother was wealthy and could have afforded it. His original intention as he entered Cambridge was to study Law. However, he became intrigued with Philosophy, Mathematics and Astronomy at one point saying, "Plato is my friend, Aristotle is my friend, but my best friend is truth." From 1663 to 1665 Newton intensified his study of Mathematics, reading from several texts that covered the most innovative fields of Mathematics of the time, including Algebra and Geometry. His studies at Cambridge were put on hold, however, at that time because the plague caused the University to close, but instead of giving up, Newton devoted his time to developing amazing advances in mathematics and science on his own. In 1666 Newton had begun developing his three laws of motion. By 1668 his accomplishments began to be recognized and he was elected to a major fellowship at Trinity College.

In 1670 Newton began teaching optics. During the plague years prior to this he noticed that white light spread out into a color spectrum in his refracting telescope lenses. Because of this he theorized that white light was not a single entity but a combination of different colors that form a spectrum of light. He proved this by passing a beam of sunlight through a prism which produced a rainbow of colors. Thinking also that there was a problem with refracting telescopes he developed a reflecting telescope. Several other prominent scientists of that time tried to disprove Newton's theory of the light spectrum and his theory that light was made up of particles. Newton however continued his work despite criticism.

In 1687 he published Philosophiae naturalis principia mathematica which is usually just referred to as Principia. Many people considered Principia to be the greatest scientific book ever written. Principia explains several important astronomical subjects such as gravity, orbiting bodies, tides, centrifugal forces and Newton's three laws of motion.

First-In the absence of a net force, an object moves with constant velocity.

Second- Force equals mass times acceleration.

Third- For any force, there is always an equal and opposite reaction force.

This work also led him to the law of universal gravitation: all matter attracts all other matter with a force proportional to the product of their masses and inversely proportional to the square of the distance between them.

In 1693 Isaac Newton suffered his second nervous breakdown and withdrew from his scientific work. He was elected president of The Royal Society 1703 and Knighted by Queen Anne in 1705. He died March 31 1727. (4.)

Basic Physics Concepts

Students will be introduced to the basic physical laws that govern planetary motion. They will participate in an activity to measure speed and learn the necessary calculations to determine speed, force and gravity.

Motion, Speed, Velocity and Acceleration

An object is in motion if it changes position relative to a reference point. Stationary objects can be used as reference points. However, movement is relative; whether or not an object is in motion depends on the reference point chosen.

The distance an object travels in a certain amount of time, must be known to calculate the speed of an object. To calculate the speed of an object divide the distance of the object by the amount of time it takes to travel that distance; speed equals distance divided by time(see figure 1). To calculate average speed divide the total distance traveled by the total time. Speed in a given direction is called velocity.

Figure 1

Speed = distance / Time

Acceleration is the rate at which velocity changes. When an object increases its speed it is accelerating. When an object decreases its speed it is decelerating, this is sometimes called negative acceleration. An object that is traveling at a constant speed can accelerate if it changes its direction. Many objects change direction continuously although they are not changing speed. This is the case in circular motion where an object moves in a circle. (1, 2)

Force

When one object pushes or pulls on another object the first object exerts a force on the second object. Net force is the combination of more than one force acting on an object.

Force is measured in newtons (N). When two forces are acting on an object in the same direction the net force is the sum of their combined forces. When two forces are acting upon an object in opposite directions the net force is the difference of their forces(see figure 2).

Figure 2

5N + 5N = 10N

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10N - 5N = 5N

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Forces are unbalanced whenever there are net forces acting on an object. This can cause the object to stop moving, start moving or change direction. Forces are balanced when two equal forces are exerted on an object from opposite directions(see figure 3). (1, 2)

Figure 3

Balanced: 5N - 5N = 0

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Unbalanced: 10N + 5N = 15N

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Or 10N - 5N = 5N

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To explain what happens to an object when a net force is present we have Newton's second law of motion(see figure 4).

Figure 4

Force = rate of change in momentum

Force= mass X acceleration (F=ma)

This is why you can throw a lighter object further than a heavier object. The heavier object has greater mass so the same force from your arm gives it a smaller acceleration. (1)

Gravity

Gravity is the force which attracts all objects to other objects. Isaac Newton came to the realization that gravity exists between all objects in the universe. Gravity is affected by two factors: mass and distance. An increase in mass results in and increase in gravity. It is directly proportional to the product of the masses of two objects. For example, when one object's mass is doubled the force of gravity between them doubles. An increase in distance results in a decrease in gravity following the inverse square law. For example when the distance between two objects doubles, the force of gravity is weakened by a factor of two squared or four. (1, 2, 3)

Newton's law of universal gravitation written mathematically as in figure 5 below.

Figure 5

F = G (m1m2/r2)

F is the magnitude of the gravitational force between the two point masses.

G is the gravitational constant.

m_1 is the mass of the first point mass.

m_2 is the mass of the second point mass.

r is the distance between the two point masses.

Inertia

Inertia is described by Newton's first law of motion which states that: "an object at rest will remain at rest, and an object moving at a constant velocity will continue moving at a constant velocity, unless it is acted upon by an unbalanced force."(2.) Planets orbiting the sun are moving at a constant velocity and there usually are no forces interfering with their movement. Inertia and gravity work together to keep an object orbiting another object. The force of gravity keeps the planet pulled toward the sun while the velocity of the planet keeps it from crashing into the sun. (1, 2, 3)

Escape Velocity

Speed in a given direction is called velocity. When an object is orbiting another object it is held in that orbit by inertia and gravity. However, that object can "escape" out of that orbit if it reaches a certain speed. That is called its escape velocity. For an object to escape Earth's gravitational pull such as a rocket it must travel at 40,200 km/hr. (1, 2, 3)

Characteristics of the Planets

The next part of the unit will introduce students to the characteristics of the planets and how they are governed by basic physical laws.

The lessons on basic physics will be comprised mainly of, but not limited to, the information in the eighth grade textbook currently being used in the classroom. A list of materials can be found at the end of this curriculum unit. Students will be taught how to calculate: speed, velocity, distance, force and acceleration using basic formulas as outlined in the text. Planetary motions will be used as examples when performing calculations. To demonstrate these formulas simple activities using toy cars and other everyday objects will be used at specified times. Also covered in the basic physics learning will be the concept of gravity. Students will compare the sizes and spherical shapes of the planets in relationship to their gravity. To demonstrate the spherical shape of Earth the size of Earth will be compared to the size of the tallest mountains on Earth. How gravity affects the orbit of planets around the sun will also be explained. To bring a personal connection to the lessons on gravity, students will calculate their own weights on various planets, moons and other objects in the solar system.

Movement of Planets

Planets revolve around the sun in moderately eccentric elliptical orbits. This is stated in Kepler's first law of motion: "the orbit of each planet about the sun is an ellipse with the sun at one focus."(1.) An ellipse is like a stretched out circle because, instead of one center point, it has two foci. The more stretched out the ellipse, the more eccentric it is. (1, 3)

An ellipse can be drawn with two pins, a loop of string, and a pencil. The pins are placed at the foci and the pins and pencil are enclosed inside the string. The pencil is placed on the paper inside the string, so the string is taut. The string will form a triangle. If the pencil is moved around so that the string stays taut, the sum of the distances from the pencil to the pins will remain constant, satisfying the definition of an ellipse(see figure 6). (9)

Figure 6

(image available in print form)

ellipse with two foci

(image available in print form)

circle

Kepler's Second Law of Motion

Kepler's second law of motion explains why planets move faster when they are closer to the sun. "As a planet moves around its orbit, it sweeps out equal areas in equal times." For example: if a planet's movement is tracked every sixty days and the area swept out between the planet and the sun is measured it will always be the same area in the same amount of time. Because the planet is at different distances from the sun at different times in the revolution some swept out areas will be long and thin and some will be short and fat but all of them will cover the same area. (1.)

Orbital Period

Kepler's third law of motion explains that a planet's average distance form the sun determines how long it will take that planet to orbit the sun. The mass of the planet and the eccentricity of its orbit do not affect its period of revolution. A planet's orbital period in years squared equals it's average distance from the sun in astronomical units cubed (one astronomical unit is approximately 150 million kilometers). This can be written as a simple formula as in figure 7 below. (1.)

Figure 7

$p^2 = a^3$

p - represents a planet's orbital period in years

a - represents its average distance from the sun in Astronomical Units (1AU= mean Earth-Sun distance)

Activities and Lessons

Activities to introduce students to motions of the planets will include working outdoors with chalk on pavement to draw elliptical orbits identifying foci and determining eccentricity. Also, students will be acting out the movements of the sun and the planets, including rotation and revolution, in groups of ten. Students will also create diagrams of the orbits of various planets and produce illustrations that show how planets sweep out equal distances in equal time in their orbits around the sun. Basic physics lessons will include calculation the speed of toy cars by measuring their distance traveled.

The final project of this unit will be a computer slide show presentation created during sessions in the school's tech lab. The rubric will include basic facts about the sun, planets, moons and other objects in the solar system such as: names, sizes and distances from other objects. Each student will do an individual project on one planet or one group of non-planetary bodies; dwarf planets or comets. The emphasis will be on the students' demonstration of each planet's or object's motion and how it is determined according to basic physics laws of motion.

Drawing Ellipses Activity

Lesson Objective: Students will be able to identify and draw ellipses and their foci.

Initiation: Teacher will begin class by asking students: What shape does the Earth make as it revolves around the sun? All answers will be accepted (about 4-5) and recorded on the chalkboard or on chart paper to refer to during lesson closure. Also, to warm students up to the lesson other questions can be asked such as: Who has drawn a circle using a compass? Who has heard the word "ellipse" before?

Materials:

Nylon cord (ten feet for each group of students)

Sidewalk chalk (three pieces for each group of students)

Teacher created handout with directions (one per student)

Procedure:

Assign students to groups of three to work together.

Read directions aloud to the class

Ask students if there are any questions about the procedure.

Walk students outdoors where there is pavement that is adequately smooth and clean for drawing.

With another adult, or student helper, demonstrate the drawing of a circle.

1 Tie the ends of the cord together.

2 One participant puts the cord around his or her waist.

3 Participant two secures the chalk inside of the end of the cord.

4 Participant one stands in one spot while participant two or participant three draws a circle around participant one.

Direct students to draw their circles

After circles are completed ask the students questions about their process and relate observations made by teachers and other students. For example:

1 What did you experience while making these drawings?

2 Do most of the drawings look like circles?

3 Why do you think this circle looks a little crooked?

4 How many central points did each circle have?

Next, direct students to draw their ellipses.

1 Participants one and two stand a few feet apart with the cord around both of their waists

2 Participant three holds the chalk inside of the cord so that the cord can move against the chalk while the ellipse is being drawn.

After Ellipses are completed ask the students questions about their process and relate observations made by teachers and other students.

For example:

1 What did you experience while making these?

2 Do these drawings look different than circles?

3 What do they have in common with circles?

4 How are they different from circles?

5 Were they harder to draw than circles?

Choose one of the drawings to use as an example. Point to it or stand in it while teaching. Point out the difference between the circle with one central point and the ellipse with two foci. Explain that planetary orbits are ellipses and that the sun is one focus of the ellipse. And that there is not anything that is important to the orbit at the second focus. Direct students to go to their own drawings and stand on:

1 Your circle

2 Your ellipse

3 The central point of your circle

4 One focus of your ellipse

5 The other focus of your ellipse

Then ask questions relating planets, the sun and their orbits to the ellipses. For example:

1 Which drawing is more like Earth's orbit?

2 Where would the sun be if that is Earth's orbit?

3 What about the other focus?

Assign students to write a paragraph about what they learned from the activity. This can be done as a wrap up exercise or as a homework assignment depending on the amount of time available for the lesson.

Measuring Speed Activity

Lesson Objective: Students will calculate the speed of an object by measuring distance divided by time.

Initiation: Ask students: Have you ever seen a speed limit sign? Have you ever known anybody who has received a speeding ticket? What is the speed limit on the highway? How is the speed of a car measured? Then briefly explain to them that they are going to measure speed in centimeters per second today.

Materials:

toy cars (six to twelve centimeters in length, self winding if possible)

meter sticks

smooth flat surface - at least three meters long, sixty centimeters wide

stop watch(s)

masking tape

Procedure:

Step 1. Divide students into groups of two or three each.

Step 2. Have each group of students create a three meter long race track on a lab table or other smooth surface by taping two meter sticks, parallel to each other, fifty centimeters apart.

Step 3. Have students pre-measure and record the distance of their race track

Step 4. One student rolls the car on the track while another times it.

(Repeat step 4 for a total of three trials for each group)

After all trials are completed show students the formula for calculating speed(see figure 8).

Figure 8

Speed = distance (in centimeters) / time (in seconds)

Step 5. Have students insert their measurements into the formula and record their data to determine the speeds of each car. This should be written as centimeters per second (cm/s).

Closure: Ask students: Why is it important to determine speed? Is it important to know the speed of objects traveling in the solar system? Why?

Follow up activities can include:

Find the average speed for the class.

Find the speed of other objects such as tennis balls or hockey pucks.

Create hypotheses to explain why some cars or other objects went faster than others. This could be a lead in to teaching friction or force.

Determining how long it takes an object to travel a certain distance at a given speed. For example: How long does it take a car traveling 60km/hour to travel 5 km.

Final Project: Computer Slide Show Presentation

Students will be instructed to create a computer slide show presentation to demonstrate their understanding of the movements of the planets. The project will consist of five to seven slides on an assigned planet. Each student will be assigned one planet or group of planetary objects such as: comets or dwarf planets. Information on slides should include physical facts, satellites, period of rotation, period of revolution, and history of the object(s).

Sources

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Appendix A: Instruction Sheet for Drawing Elipses Activity

Drawing Ellipses Activity

Understanding the shape of planetary orbits

Materials:

Sidewalk chalk

Nylon chord (one piece-ten feet long)
Direction sheet

This activity will be done in groups of three students each as assigned by the teacher

Step one: Drawing a circle

1 Tie the ends of your cord together
2 Choose one person in your group to be the center
3 Place the cord around the ankles of the person in the center
4 Choose one person to draw the circle
5 The person drawing the circle should secure the chalk inside of the cord
6 Pulling the cord taught, draw a circle around the center person

Draw and explain your observations:

Step two: Drawing an ellipse

1 Choose two people to be the foci of the ellipse and have them stand a few feet apart
2 Place the same cord used for the circle around both of their ankles
3 The third person secures the chalk in the cord and pulling it taught draws an ellipse around the two foci

Draw and explain your observations:

Appendix B: Rubric for Computer Slide Show Presentation

Slide Show Scoring Rubric

Name(s) ________________________

Planet or Solar System objects: ________________________

Project Includes:

5 points

each

5-7 slides ________

5 Physical facts ________

5 Movement Facts ________

10 History facts ________

40 points

each

Explanation of movement related to Kepler's laws ________

Explanation of movement related to Newton's laws ________

Total ________

Recommended Websites

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Dwarf

http://www.perthobservatory.wa.gov.au/information/planet_defn.html

http://pds.jpl.nasa.gov/planets/welcome.htm

http://www.nineplanets.org/

http://www.nasm.siedu/etp/