QUANTUM QUEST

A CASSINI SPACE ODYSSEY 3D

Science & Space Education

Education Resource Guide for Teachers

Reuben H. Fleet Science Center

- Solar System Lessons and Activities for Grades 4-12
- Keywords & Visual Examples
- NASA Unmanned Space Missions
- Resources & References
- Meets National & California Standards for Science & Math

GRADES 4-12

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Jupiter 9 PRODUCTIONS

Download this Education Resource Guide at:

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GUIDE PRODUCED/PRESENTED BY FLEET MUSEUM AND JUPITER 9 PRODUCTIONS

Quantum Quest, Science & Space Education

A message from Filmmaker/Scientist
Dr. Harry Kloor, Ph.D. Physics, Ph.D. Chemistry

Quantum Quest: A Cassini Space Odyssey is designed as a means to advance science literacy through a large format film, its website www.qqthemovie.com, and ancillary material like this booklet. Each booklet contains pre and post theater materials that can be used by kids, teachers, and parents to enhance their film learning experience. Educators may freely use the characters for non-profit purposes.

With an all star cast, and Hollywood approach to storytelling, Quantum Quest seeks to appeal to everyone, from the science enthusiast to the novice who is fearful or uninterested in science or space exploration. On its surface, Quantum Quest is a sci-fi action film set in a scientifically accurate rendering of our solar system in 3-D stereoscopic. Visually, the film blends computer animation with the fantastic images captured during recent NASA and NASA/ESA space explorations, including the international Cassini Huygens mission. The audience is taken on a simulated solar safari, exploring the inner planets between the Sun and Saturn, and touring the Saturn system's, rings and moons. The film concludes with a Grand Canyon-like flight over the surface of Titan, using image and radar data from Huygens and Cassini space craft.

Science is imparted in the film through its characters (particles and concepts) and the actions they take to save the Cassini-Huygens spacecraft. Since the inception of the project, the film has been closely reviewed at every stage by JPL for scientific accuracy. In addition, Dr. Peter Diamandis, the founder of X Prize, and other scientists, have closely reviewed the film to ensure science concepts and all depictions of the Space Discoveries and actions of the Cassini-Huygens space craft are scientifically accurate.

The story of Quantum Quest takes place in a fantastic atomic world, where the forces of Knowledge and Good are represented by positive matter and light who work for THE CORE (William Shatner), and the forces of Evil and Ignorance represented by anti-matter and concepts who work for THE VOID (Mark Hamill). The hero of our story is a photon, named DAVE, played by Chris Pine. Dave is forced from his home in the Sun and must save the Cassini Huygen's space craft from FEAR (Samuel L. Jackson), GENERAL IGNORANCE (Jason Alexander), and MAJOR MORON (Jason Alexander). Dave is assisted on his journey by solar surfing protons lead by JAMMER (Hayden Christensen), a solar neutrino RAYNA (Amanda Peet), Gal 2000 (Sandra Oh), Razor (Doug Jones), Admiral Halifax (James Earl Jones), and a photon who is searching for a free quark which he can't ever seem to find by the name of MILTON (Robert Picardo).

We are honored to have Neil Armstrong, the first man to walk on the moon, voice the character of Jack Doohan. This is Neil's first and only involvement in a film. We are also thankful to Abigail and Spencer Beslin who voiced the two kids who are in the scene with Neil.

For more information visit www.QQtheMovie.com

The Reuben H. Fleet Science Center's education team has provided this Educator's Guide to add the value of inquiry based activities inspired by the action in Quantum Quest. We encourage teachers to use this material to help launch their students into the fun of seeing how far their curiosity can take them towards a better understanding of our Solar System.

Jeffrey Kirsch, Executive Director

This Teacher's Guide is appropriate for grades 4-12 and grade levels are suggested for each activity. It is most useful when accompanying the film, but is a valuable resource on its own. Teachers are strongly encouraged to adapt the activities included in this guide to meet the specific needs of the grades they teach and their students. All activities developed are consistent with the National Standards for Science and Math but are not referenced specifically due to space constraints and differences in standard use throughout the nation.

GAL 2000

"I am Cassini's brain, its central computer. Cassini-Huygens is a real space joint NASA/ESA/ASI mission to explore the Saturn system. The spacecraft was launched in 1997."

"Gal 2000" is voiced by SANDRA OH. Sandra is best known for her role in *Grey's Anatomy*. She is also in, *Blindness*, *For Your Consideration*, *The Night Listener*, and our favorite, *Sideways*.

RAZOR

"Like my bro Jammer, I surf the solar winds. When I was young I used to play Novaball and I was awesome! My girlfriend, Shalla-Bal draws the most epic stylish lines in the magnetic solar winds that roll through your solar system."

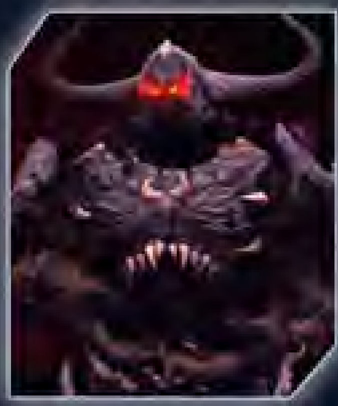
"Razor" is voiced by DOUG JONES. Doug has played numerous cool characters and creatures. He was the Silver Surfer in *Fantastic Four: Rise of the Silver Surfer*, *Fauno* and Pale Man in *Pan's Labyrinth*.

MILTON

"I'm a free quark miner, and while most earth scientists think finding a free quark is a near impossibility, I believe I will find one. Quarks and leptons are the most fundamental particles in the Universe. Margaret is my trusted companion."

"Milton" is voiced by ROBERT PICARDO. Robert was the DOCTOR in *Star Trek: Voyager*. He has joined the cast of *Stargate Atlantis*. Watch Robert in the film *Sensored*.

THE VOID



"I am that which existed before the Universe was created. I am nothingness, emptiness. Help me erase the Universe."

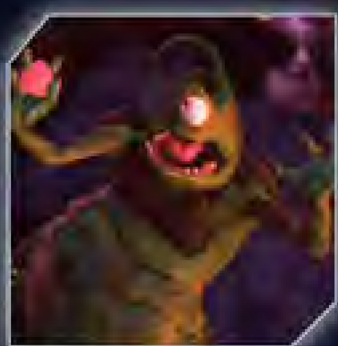
"The Void" is voiced by MARK HAMILL. Mark was Luke Skywalker and the voice of Joker in the *Batman* series.

GENERAL IGNORANCE

"Ignorance is bliss! My good friend Major Moron and I have only a quarter of a brain— if we had more perhaps we wouldn't be so stupid. Being stupid can have its advantages.

"General Ignorance" is voiced by TOM KENNY. Perhaps best known for his work as *Sponge Bob*, Tom has voiced a billion voices! Okay, not a billion but it seems like it. You can hear him in *Transformers* the animated series.

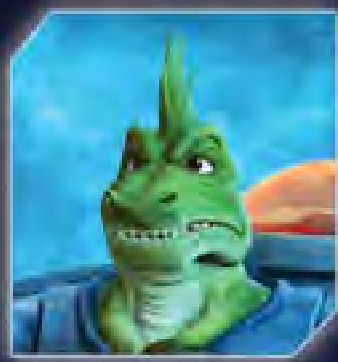
MAJOR MORON



"The keys to being a 'Major Moron' like me are simple. First, make sure you have as little brains as possible. Next, don't pay attention at school and don't use any of the educational materials on the Quantum Quest site."

"Major Moron" is voiced by JASON ALEXANDER. Jason is best known for playing George in *Seinfeld*, and has appeared in numerous movies and TV series. Jason is a very experienced voice actor and brilliant comedian.

GENERAL HALIFAX



"I'm Admiral Halifax, I represent a deuteron, which is the nucleus of heavy hydrogen. I lead The Core's eternal war against the forces of The Void."

"Admiral Halifax" is voiced by JAMES EARL JONES. James began his magnificent acting career in Shakespeare's *Othello*, and, most famously, in *The Great White Hope*. He is perhaps best known as the voice of Darth Vader in *Star Wars*.

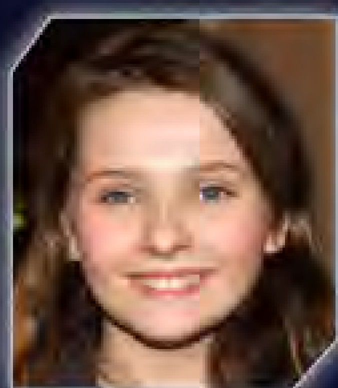
ANTHONY

"I am a championship video game player, and when I grow up I am going to develop video games. So, I try to learn as much as possible about science and math, because this will help me create great games."

"Anthony" is voiced by SPENCER BRESLIN. Spencer burst into the acting scene with his wonderful performance in *The Kid* with Bruce Willis.

JEANA

"Science is cool. I love playing video games, baseball, and riding my bike, and, science lets me understand all of these things. When I grow up I want to be the first professional baseball playing astronaut."



"Jeana" is voiced by ABIGAIL BRESLIN. Abigail was the lead in *Definitely, Maybe*; *Nim's Island* and *Kit Kittredge: An American Girl*.

Introduction

Quantum Quest is an animated science fiction adventure film that captures scientifically accurate renderings of our solar system. Initiated at JPL/NASA, Quantum Quest blends computer animation with astounding real images and radar data from a spectrum of ongoing space missions.

As our characters surf through the Solar System, the audience will see the real surface of planets and moons in 3D, beginning with a journey over the blazing surface of the Sun (via images from NASA's Solar and Heliospheric Observatory — SOHO). From the Sun the viewers are taken on a journey through the Solar System, over the spider craters of Mercury, through the dense clouds of Venus — racing through the canyons of Mars to the Moons of Saturn.

The film concludes with a Real 3D tour of Titan, a moon of Saturn that has rivers, giant lakes of natural gas, and even methane rainfall!

Through DAVE and his friends, the viewers are taken on an atomic odyssey that inspires them to learn more about physics, chemistry and the Universe.

Propulsion Lab (JPL), NASA's facility in Pasadena, California, has been a part of this production process and has ensured scientific accuracy of the physics concepts and representations, the correct engineering depictions of the Cassini spacecraft and Huygens probe as well as all NASA images.

QUANTUM QUEST A CASSINI SPACE ODYSSEY 3D

cast of characters

Quantum Quest features dynamic, wonderous characters that represent physics concepts. Our mythology centers on an epic battle of knowledge/life vs. ignorance/ non-existence, the outcome of which will determine the fate of the universe.

DAVE is a photon, a being of light, who lives in Sun City — not Arizona, but at the core of the Sun. Sun City is inhabited by Photons, Neutrinos and Proton citizens, all living in tranquility and unity. Until one day DAVE is forced to leave the Sun and engage in a conflict between The CORE (knowledge) and THE VOID (absolute nonthingness). DAVE's quest is to save his people, the Cassini Spacecraft, and ultimately, the universe from annihilation.

ADMIRAL FEAR, GENERAL IGNORANCE, MAJOR MORON and ZERO, an anti-proton warrior, all endeavor to divert DAVE from his mission. But with the help of neutrino, RAYNA, and two protons, JAMMER and RAZOR, DAVE goes on to fulfill his destiny.

storyline

Quantum Quest opens with a stunning view of the planet Saturn. Heading toward this giant world is NASA's spacecraft Cassini-Huygens. are in the CalTech auditorium watching video presentation through two students' points of view.

"Welcome to the atomic realm of Quantum Quest, where a war wages at the edge of Earth's solar system between the forces of THE CORE and THE VOID." THE CORE, a being of knowledge and light leads the citizens of Sun City against… THE VOID, a being of nothingness, desirous that all knowledge and life be destroyed, who leads an army of anti-matter.

We follow the probe into space as we scan radio stations to settle on Casey Kasem's broadcast:

"In other news… Mission Control has just announced… in just three short weeks the Huygens Probe will punch through the thick cloud-covered veil that surrounds Titan, Saturn's largest moon. What marvelous secrets will Huygens uncover?"

We then dive into the sun's core and move back in time one million years to Sun Coast Middle School Stadium where we hear the thunder of cheering crowds and a Novaball game in progress. Here we meet the main characters, DAVE, a photon, and RAYNA, a neutrino, who go on to help their team, the Solar Winds, win the Novaball competition.

As rewards, Admiral Halifax of the CORE offers RAYNA and DAVE high positions in Operations. RAYNA accepts and departs in Ranger status, but DAVE chickens out and remains behind. After all, he's no Milton Rah, all-time hero of the good guys.

Meanwhile, inside the Kuiper Belt, just beyond Pluto, the Rangers battle a force of anti-proton ships. The Proton fleet suffers heavy losses and aboard Admiral Halifax's ship the mood is grim. RAYNA is tasked with getting a message out for help. She rockets into a field of asteroids, barely escaping with her life. In the camp of THE VOID and the dark forces, we meet kooky characters such as MAJOR MORON and GENERAL IGNORANCE, who lend a bit of levity to this grave situation. The army of THE VOID consists of GELL-MAN ghosts, the essenceof non-existence. Their plan is to kill the

Rangers and destroy the Cassini spacecraft. Back at the stadium, RAYNA reunites with DAVE. GELL-MAN ghosts follow her in and DAVE is forced to take a stand. RAYNA begs him to find the Cassini Commander and give him a message that is hidden in a gem. She shoves the gem into his chest and he takes off to seek his destiny.

In DAVE's quest for the Cassini Commander he befriends a group of Surfer Protons who help him search for the spacecraft. On their journey, they battle the GELL-MAN ghosts on a perilous surfer ride through the Solar System. They zoom by Mercury's spider crater and pass by the thick clouds of Venus. They scoot over Mars' moon Phobos and toward the red planet. There they fly through the giant canyon, Valles Marineris.

At the same time DAVE is nearing Saturn's system, ADMIRAL FEAR, leader of the VOID is making plans to destroy Cassini. Cassini represents knowledge and all knowledge must be destroyed.

As DAVE descends onto Saturn's moon, Enceladus, with its field of icy monoliths, he spies another photon like himself, but much older. It is Milton Rah, great military commander of all time, leading a double-ass Tarmouth named Margaret. Rah is now a burnt-out photon, mining the moon's surface. When Rah sees the "gem" DAVE is carrying, he taps it and out comes a message: Cassini is in imminent danger.

In a struggle to save the spacecraft, DAVE must call on his reserves and unleash the hero that has been hidden within. He locates Cassini and enters the craft. There a voice welcomes him — the voice of GAL 2000, the brain of Cassini. GAL is excited about downloading data to Earth from the Huygens probe on the moon Titan.

In a final confrontation with FEAR, DAVE, with the help of Milton Rah, defeats the dark VOID and saves Cassini-Huygens. DAVE returns home a hero in RAYNA's eyes… and in his own.

From Casey Kasem: *"I've just been informed Huygens is punching through the bottom cloud layer of Titan. An image is forming on my screen. Oh my… it's… it's amazing!"*

QUANTUM QUEST A CASSINI SPACE ODYSSEY 3D

Activity 1

Toilet Paper Solar System

Grades: 4-5

Objective:

Students will create a scale model of the solar system to demonstrate the varied and enormous distances in space.

Materials:

Rolls of two-ply toilet paper (plain white rolls work best)
Felt tip markers (10 different colors, if possible)
Clear tape (for repairs)
Planetary Distances handout

Teacher's Prep:

100 sheets of toilet paper stretch out to nearly 42 feet. Be sure you have enough room for the models before you start. Test the felt tip pens on a sheet of toilet paper.

Make sure the felt pens are not too wet and that they do not easily tear the paper.

To Do and To Notice:

1. Begin this activity by discussing the concept of scale. Discuss the usefulness of models as representations of objects that are either too large to easily fit into the classroom, or too small for our unaided eyes to detect important features. Comparing a toy car to a real car, and figuring out the scale at which the toy was produced may be a good introduction to this topic.

2. Give each group of students a roll of toilet paper, a copy of the Planetary Distances table, and a set of markers.

3. Have the students roll out a few sheets of toilet paper. Ask them to place a dot between the first two sheets of toilet paper. This dot represents the Sun. Have the students write the word sun beside the dot.

4. Have the students continue unroll the toilet paper outward from the Sun. They will use the Planetary Distances Table to mark off the locations of the other planetary bodies in the model.

5. Since keeping track of the number of sheets of toilet paper can get confusing, you may wish to have the students calculate the number of sheets of toilet paper between the each object in the model. For instance, if Jupiter is 13. 2 sheets from the Sun and Saturn is 24.2 sheets from the Sun, then Saturn is 11 sheets from Jupiter.

6. Remind the students that the numbers in the table represent the number of sheets of toilet paper needed to reach the orbit of each planet from the Sun. Ceres, the largest asteroid, is used to represent the asteroid belt.

7. When the students are finished marking off the planets, have them stand back and look at their models. Ask them if they are surprised by any of the distances?

8. Ask the students why they do not see the solar system drawn to scale like this in their textbooks. How big would the books need to be? Ask the students to locate the planet that is closest to the "half-way point" between the Sun and Pluto.

9. Wrap-up the activity with a review of the advantages and disadvantages of using models to study astronomy. Ask the students how models might be helpful. Ask them if they can think of any ways that the toilet paper model might be inaccurate. If they have trouble coming up with ideas, ask them if they think all of the planets are really lined up in a straight line from the Sun.

In the Film:

As Dave and the surfer protons attempt to escape the Gell-Man ghosts, they pass by several planets including Mercury, Venus,and Mars. It may appear that these planets are relatively close to one another, but in reality the distance between them (and all of the other planets in our solar system) is quite large.

What's Going On:

Even though it occupies a very small corner of the Milky Way galaxy, our solar system is still a very big place. If we were to map out the solar system in actual miles, we would have to travel around Earth's equator 1,445 times just to travel the distance between the Sun and Mercury (the closest planet).

Be aware that some scale models can lead to misconceptions. Because the planets in the toilet paper solar system have been arranged in a straight line out from the Sun, some students may believe that they always appear in line in the solar system. In fact, the planets do not revolve around the Sun in perfectly circular orbits. Instead, they travel in elliptical orbits so that at some points they are closer to the Sun and to one another than at other points. For this activity, you are using the average distance between each planet and the Sun. Keep in mind that sometimes each planet is slightly closer to the Sun and sometimes it is a little farther away.

Background

Interplanetary travel is extremely difficult due to the almost unimaginable distances between the planets in our solar system. Voyager II, traveling at nearly 50,000 mph took 12 years to reach the planet Neptune. Voyager 1, the most distant and fastest-moving human-made object as measured from Earth, was launched in 1977 and is only now reaching the "edge" of the solar system.

In order to study objects or systems that are too small or too big, scientists build scale models. The parts of the scale model keep their same relationship to each other, but the model is much smaller or much larger than the actual object. We can make a scale model of the distances between the planets using almost anything as our reference – including squares of toilet paper.

Because the space between objects in our solar system is so vast, astronomers often measure distance in astronomical units rather than kilometers or miles. The Astronomical Unit (A.U.) is defined as the average distance of the Earth from the Sun, and is roughly equal to 150 million kilometers (93 million miles).

Taking it Further:

Tell the students that astronomers believe that there is a vast cloud of frozen comets called the Oort Cloud that surrounds our solar system. This cloud lies approximately 50,000 times farther from the Sun than the Earth. Challenge the students to figure out how many sheets of toilet paper they would in order to put the Oort Cloud on their model.
(Answer: 50,000 x 2.5 = 125,000 sheets.)

Using the Planetary Distances table, encourage the students to figure out the distances between planets in Astronomical Units. Remind them that 1 A.U. is equal to 150 million kilometers, or 93 million miles.

Planetary Distances Table

Planetary Body	Distance from Sun (km)	Squares of Toilet Paper Out to Planet's Orbit
Mercury	57,910,00 km	1.0
Venus	108,200,000 km	1.8
Earth	149,600,000 km	2.5
Mars	227,940,000 km	3.8
Ceres	414,436, 363 km	7.0
Jupiter	778,330,000 km	13.2
Saturn	1,429,400,00 km	24.2
Uranus	2,870,990,000 km	48.6
Neptune	4,504,000,000 km	76.3
Pluto	5,913,520,000 km	100.0

Did you Know:

The moon is our closest neighbor in the solar system, but it is still far away. If we could build a freeway to the moon and we drove 70 miles an hour, it would still take 135 days to get to the moon.

Keywords:

Astronomical Unit – A unit of length roughly equal to the mean distance between the Earth and the Sun. It is approximately 150 million kilometers, or 93 million miles.
Model – A representation of something, usually on a smaller scale.
Scale – The ratio between the size of something and a representation of it.

Acknowledgments: Astronomical Society of the Pacific

Activity 2

Making an Impact

Grades: 4-5

Objective:

Students will investigate how craters are formed and understand the relationship between projectiles and the landforms they create.

Materials:

- Baking pans, dishpans or cardboard boxes at least 10 centimeters deep.
- Sand
- Flour
- Cocoa powder (optional)
- Various sizes and shapes of projectiles (magnetic marbles, BBs, ball bearings, magnetic rocks, etc.).
- Magnets
- Measuring tapes
- Pieces of cardboard to smooth the surface

Teacher's Prep:

This activity can be messy. You may want to arrange to do the investigation outside. Or, you can cover the workspace with newspapers or an old tablecloth. You will need to create a pan of surface material for each group of students.

Fill each pan with approximately 7 cm of sand. Place a thin (approximately 2 cm) layer of flour on top of the sand and use the cardboard to smooth the surface. If desired, sprinkle a light coating of cocoa powder on top of the flour.

Using objects of different mass dropped from the same height will allow students to study the relationship between the mass of the object and the crater size. Dropping objects of constant mass from different heights will allow the students to study the relationship between the velocity of the object and the crater size.

To Do and To Notice:

1. If possible, show students some pictures of lunar or Martian craters from the Internet or textbooks. Ask them how they think the craters were formed.
2. Divide students into groups and give each group a pan of sand/flour, a set of projectiles, a magnet, a measuring tape and a piece of cardboard.
3. Give the students a few moments to practice dropping the projectiles into the pan one at a time. Encourage them to drop the objects from different heights and to drop objects of different sizes. Ask them to look closely at the craters formed by the projectiles. How are the craters similar? How are they different? The students should use the magnets to remove the projectiles from the sand/flour mixture. They can use the cardboard pieces to gently smooth the surface of the substrate when necessary.
4. Gather the class together and ask the students what they observed. Brainstorm some variables that might influence the size and shape of craters (height from which crater is dropped, mass of the projectile, etc.).
5. As a class, choose a couple of variables that are easily testable, such as height and mass. Come up with a plan to determine how these variables affect the depth, width, and shape of the impact craters. For instance, students might test the effect of height on the impact craters, by dropping the projectiles from three pre-determined heights and then measuring the width and depth of the craters. Similarly, students might test the affect of the mass of the projectiles by dropping objects of three different masses from the same height.
6. You may choose to have the whole class test one variable or to have the groups decide which variable they want to test. Be sure to discuss the importance of keeping all other variables constant during the investigations.
7. Have the students complete their tests and record the widths and depths of their craters in a table. It may also be helpful for them to sketch a picture of their craters.
8. Have each group of students share the results of their investigations. You may choose to have the students create graphs or other visual representations of their data to share with their classmates.
9. Wrap-up the activity with a comparison of the classroom-created craters with the pictures of actual craters. How are the craters similar? How are they different? Is the flour and marble investigation a perfect model of cratering in the solar system? Why or why not?

In the Film:

As Dave and the surfer protons catch a ride on the solar wind, they check out the spider crater on Mercury, a massive example of an impact crater. The crater was formed more than 3.8 billion years ago when Mercury was hit by a large space rock. Later in the film, we observe the cratered moons of Saturn including, Phoebe, Tethys, Dione, and Rhea.

What's Going On:

The size and speed of a projectile determines the size of its impact crater. The bigger the object and the faster it travels, the bigger the crater. This is because bigger and faster projectiles release more energy when they collide with another body, mostly in the form of kinetic energy. Other factors, such as the weight of the projectile, its composition, the angle of its landing, and the type of surface it hits will also determine the shape and size of an impact crater.

While this activity helps students understand some of the factors that affect the cratering process, the model is not completely accurate. Unlike marbles and BBs, most large cosmic projectiles explode on impact with the surface.

Background

Craters are the most widespread landforms in the solar system. They can be found on all of the terrestrial planets – Mercury, Venus, Earth and Mars – as well as the surfaces of asteroids and the rocky, ice covered moons of the outer gas planets. These circular features are formed when projectiles (also called impactors) smash into the surface. The explosion and excavation of materials at the impacted site creates a pile of rock (called ejecta) around the circular hole as well as bright streaks of target material (called rays) thrown for great distances. The craters left by impacting objects can reveal information about the age of a planet, as well as the nature and composition of the planet's surface at the time the crater was formed. The surfaces of the Moon, Mars and Mercury, where geologic processes stopped millions of years ago, record this bombardment clearly. On the Earth, however, craters are continually erased by erosion, volcanic resurfacing, and tectonic activity.

Taking it Further:

Ask the students what would happen if they changed the angle of impact. How could this be tested? Have the students design investigations to test their ideas and then discuss the results of their experiments. They may notice that as the angle of impact is changed, the rays will be concentrated and longer in the direction of impact. A more horizontal impact angle produces a more skewed crater shape.

Did you Know:

The giant basin that covers about 40 percent of the surface of Mars, sometimes called the Borealis Basin, is actually the remains of a colossal impact very early in the solar system's formation. The basin, 8,500 km across and 10,600 km long, is larger than the combined area of Asia, Europe and Australia, and about four times wider than the next biggest impact basins known, the Hellas basin on Mars and the South Pole-Aitken basin on the moon.

Keywords:

Crater – A [usually] circular depression in a surface caused by an impact. **Ejecta** – Material tossed out of the crater.
Rays – Ejecta tossed out of the crater at high speed. The material forms long lines pointing directly away from the crater.
Rim – The raised edge of the crater. It is formed by the outwards and upwards compression of the crater walls, not ejecta.

Activity 3

Planetary Weather Reports

Grades: 4-5

Materials:

Internet access

Print resources

Art supplies (poster board, markers, etc.) for creating props

Video camera (optional)

Teacher's Prep:

Arrange for groups of students to have access to computers. In addition, gather books and other print resources for students to look up planetary weather information.

Objective:

Students will research the weather conditions on other planets in our solar system and then compare and contrast the different environments.

To Do and To Notice:

1. Ask students what they know about weather. To spark conversation, pose the following questions:
   - What is weather?
   - What are some examples of weather conditions or patterns?
   - Where does weather take place?
   - How does weather occur on Earth?
   - What are at least two elements of weather?
2. After the preliminary discussion, tell students that they might be surprised to learn that weather is not unique to Earth. In fact, different types of weather can be found on every planet in our solar system.
3. Review some of the background information on air temperature, humidity, and air pressure with the students.
4. Break the students into eight groups and assign each group to research a different planet. They will need to gather enough information to present a planetary weather report to the rest of the class. The students should include the following information in their reports:
   - The atmosphere, temperature, air pressure, and humidity on their planet. (This information may not be available for all planets, the students should record as much as possible.)
   - Any unusual weather that occurs on that planet.
   - Any explanations scientists have for the unusual weather.
5. After students have gathered information about weather on each of the planets, challenge them to create weather reports to present to the other groups (or to students in another classroom). They may want to use some of the art supplies to create props, graphs, etc. Alternatively, you can have the students create multimedia reports using PowerPoint or iMovie.
6. If possible, videotape the students giving their presentations and play the videos for students or parents.
7. Conclude the lesson by asking students why they think weather is so much more extreme on other planets than it is on Earth. Help students understand that the lack of water, varying geological features, proximity to the sun, and the lack of a protective atmosphere result in extreme weather systems.

In the Film:

Dave and the surfer protons travel through the clouds of Venus. These clouds are composed mainly of sulfuric acid along with chlorine and fluorine and they can swirl at rates of up to 300 km/hour. Later we observe earthquakes, geysers, and ice plumes as Dave and Milton race across Enceladus, a moon of Saturn. Many other planets and moons in our Solar System have weather that is different from the conditions on Earth.

What's Going On:

Every planet in the solar system has unique weather. While Earth's weather is the most varied, many other planets have amazing and tempestuous atmospheric conditions. For example, Mercury experiences scorching temperatures on the side of the planet that is exposed to the Sun and freezing temperatures on the side facing away from the Sun. Venus also experiences extremely hot temperatures due to its thick atmosphere of carbon dioxide. The temperature on Venus can reach 860 degrees Fahrenheit, which is hot enough to melt lead.

While the temperature on Mars is usually well below freezing, it does experience seasons and widely varying weather conditions. For instance, Mars is home to intense dust storms and tornadoes that can tower up to 5 miles high. Mars also has clouds, and ice at its poles.

Because of the great distance between Earth and the gas giants, scientists have less information about these planets. Most of the gas giants experience great storms and/or strong winds. Jupiter's Great Red Spot is probably the most well known storm. This hurricane-like storm is 15,400 miles across at its widest point. Storms can last longer than 300 years on Jupiter. Saturn also experiences storms and very strong winds, although scientists don't know much else about the weather conditions on this planet.

Uranus's atmosphere contains methane, hydrogen, and helium. Under the atmosphere may be an ocean of hot water and ammonia. Neptune looks much like Uranus, with clouds and storm centers in its atmosphere. One of its moons, Triton, is one of the coldest places known in the solar system. Neptune also has volcanoes, which release liquid and gaseous nitrogen. These substances freeze and give the landscape a snowy look.

Background

Weather is the state of the atmosphere at a given time in a particular place. It is a mix of heat or cold, wetness or dryness, calm or storm, clearness or cloudiness. The three key factors that determine our weather are air temperature, air pressure, and humidity. Air temperature is the measure of the amount of heat in the atmosphere. Air pressure refers to the pressure resulting from the weight of the atmosphere. Air pressure decreases with increasing altitude. Temperature variations also result in changes in air pressure. Cold air is dense, so it exerts relatively high pressure. Warm air exerts relatively low pressure. In general, high pressure usually brings fair weather, while low pressure brings cloudy, stormy weather.

Humidity is the amount of water vapor or moisture in the air. Air that contains the maximum amount of water vapor is referred to as saturated. When meteorologists refer to relative humidity, they are comparing the amount of water vapor actually in the air with the amount of water present at saturation. In other words, relative humidity is the amount of water vapor present in the air compared to the greatest amount possible at the same temperature. When the air is at saturation, clouds form, and there is a good chance that it will soon rain.

Did you Know:
Some scientists consider Venus to be Earth's twin planet because it is very similar in size and mass. However, there are many differences between the two planets. For instance, Venus is the hottest planet in the solar system, with an average temperature of 462 degrees Celsius (865 degrees Fahrenheit). In comparison, the hottest temperature ever recorded on Earth is only 58 degrees Celsius (136.4 degrees Fahrenheit). The atmospheric pressure at the surface of Venus is also considerably greater than Earth. If you could stand on the surface of Venus, you would experience 92 times as much atmospheric pressure as Earth.

Taking it Further:

Have the students imagine that they are designing the first permanent settlements on Mars. Have them create pictures of their settlements and explain how the atmosphere, temperature and air pressure would affect daily life.

Keywords:

Air Pressure – The pressure resulting from the weight of the atmosphere.
Air Temperature – The measure of the amount of heat in the atmosphere.
Humidity – The amount of water vapor in the air.
Weather – The state of the atmosphere with regard to temperature, cloudiness, rainfall, wind and other meteorological conditions.

Acknowledgments:
Discovery Education (http://school.discoveryeducation.com)

Activity 4

Fingerprints of Light

Grades: 6-8

Objective:
Students will analyze how white light can be refracted to form a color spectrum that gives distinctive information about its source.

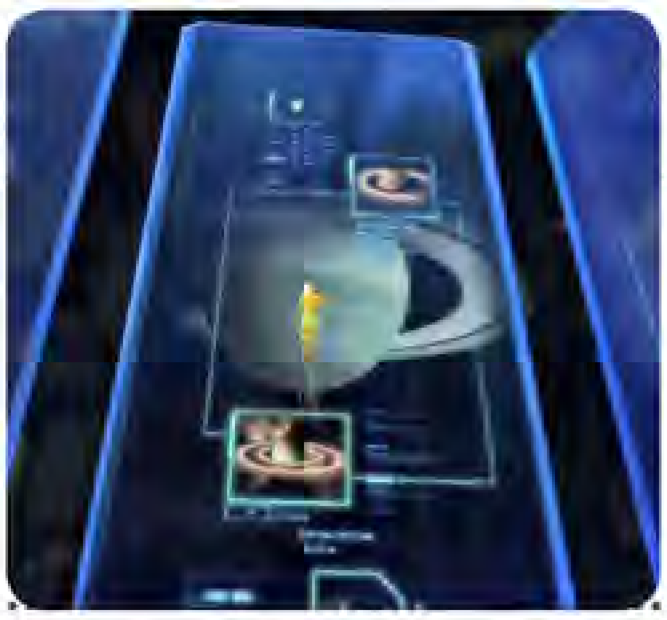
Materials:
Assorted boxes
(cereal, cracker, or cookie boxes work well)
Scissors
Old CDs
Duct tape
Clear tape
Permanent markers
Rulers

Teacher's Prep:
Depending on the age of your students and the amount of time you can devote to this lesson, you may want to cut the CDs ahead of time. Students will work individually or in pairs for this activity.

To Do and To Notice:

1. Distribute boxes and old CDs to the students.
2. Have the students select one end of the box and close the flaps.
3. Using their rulers and markers, have them draw a square approximately 3 cm X 3 cm in the center of the flaps.
4. Show the students how to open the flaps and cut along the lines to create an opening.
5. When they are finished cutting, the students can tape the box flaps down. They should have a square cutout on one end of the box.
6. Now have the students use their markers and rulers to draw a square on their CDs that is slightly bigger than the opening on their boxes. They will use their scissors to carefully cut out the square.
7. To remove the silver backing from the CD, the students will need to place a piece of duct tape on the CD and press down firmly. Have them quickly pull the tape from the CD. They should remove some of the silver coating along with the tape. They may need to repeat this process a few times until all of the silver backing is removed.
8. Once the students have removed all of the silver backing from their CD pieces, they should lay the CD square over the opening in their box and secure it with clear tape.
9. Have the students rotate the box so they are looking at the opposite end.
10. They will use their markers to draw a thick line approximately 3 mm wide by 3.5 cm long. They should cut along the mark they just made to create a very narrow slit.
11. Have the students close the flaps and tape them shut.
12. Tell the students to look through the end of the box with the CD while aiming the slit at a light source. Ask them what they observe. They should see a spectrum on the side of the box.

In the Film:
While talking with Gal 2000 in the Cassini spacecraft, Dave asks what all of the sensors are for. Gal 2000 explains that the sensors are needed to analyze the wide spectrum of light that reflects off Saturn and its moons. Each sensor provides different information. For example, visible light reveals form. A colorful image of the light spectrum appears on the screen, with text identifying each frequency group.



What's Going On:

Visible light from the sun is actually made up of many different colors, or frequencies, of light. The CD in the spectroscope acts like a diffraction grating, spreading light into its component colors. The surface of the CD contains many small grooves. When light hits the CD, these little grooves separate the colors so they reflect at different angles, creating a spectrum on the wall of the spectroscope. Violet light (the highest frequency of visible light) is at one end of the spectrum and red light (the lowest frequency of visible light) is at the other.

Background

When **atoms** of different materials are excited by electric current or heat or other sources of energy, they glow with a unique spectrum. Atoms of different elements have different colors in their spectra. These characteristic color patterns represent specific atoms just as fingerprints serve to identify different people.

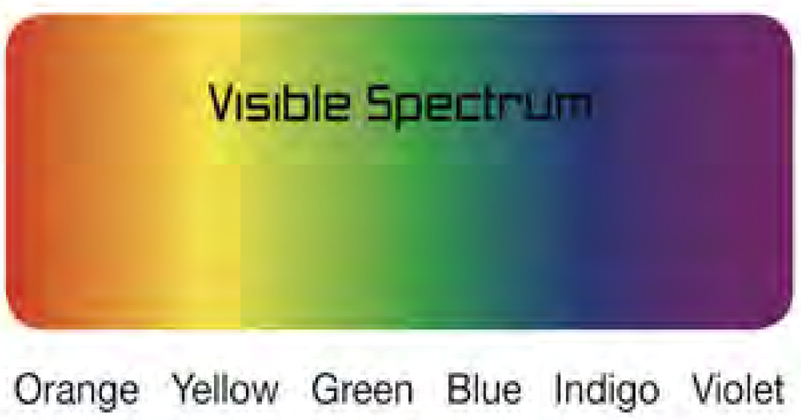
Although we think of sunlight or starlight as white, it is really composed of a spectrum of colors. Scientists can tell the elements present in a star by looking at its light through a spectroscope. When scientists analyze the spectrum from a star, they will see either dark or bright bands in certain locations. This means that certain wavelengths of light are being absorbed or emitted by the star. In this way, the scientist can discover which elements are present in the star.

The chemical composition of a star also indicates its age. If a star contains a high percentage of elements other than hydrogen and helium, it is relatively young. Older stars contain few of these other elements. Our own star is middle-aged compared to other stars.

Did you Know:
Spectroscopy began in 1666 when Sir Isaac Newton discovered that white light passing through a glass prism split the light into a rainbow. To confirm this, Newton passed the rainbow through another prism and it recombined into white light.

Taking it Further:

Have the students compare the spectra of various light sources, such as sunlight, incandescent light, LED light, fluorescent light, or even a candle flame. Tell them to look for specific colors and to notice the spacing between the colored lines. They may notice that sunlight and incandescent light bulbs produce continuous spectra in which all of the colors merge smoothly into one another. In contrast, the light from a fluorescent bulb produces distinct colored bands.



Keywords:

Diffraction – The slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening.

Spectroscope – An instrument used to view a light source so that it is split into its component colors.

Visible Spectrum – The range of wavelengths of visible radiation.

Wavelength – The length of the space between peaks of the waves in which light travels. The wavelength is always the same for any given color of light.

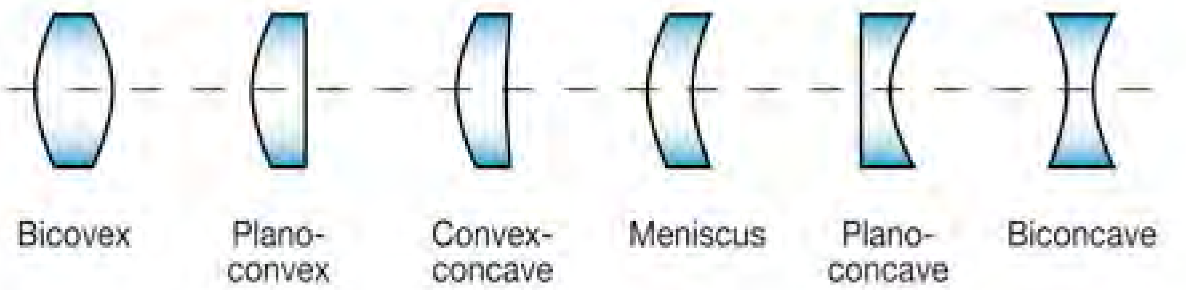
Activity 5

Gelatin Optics

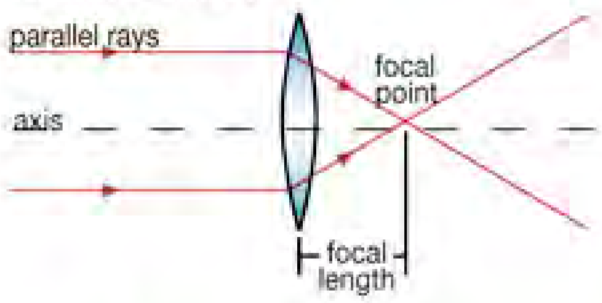
Grades: 6-8

Objective:

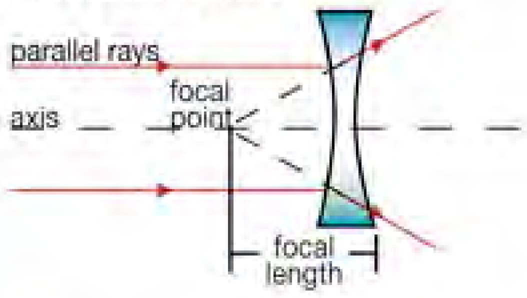
Students will identify types of lenses and examine how light is refracted through these different lenses.



Convex Lens



Concave Lens



Materials:

Clear unflavored gelatin
(light-colored, flavored gelatin will also work)
Shallow baking pan
Sharp knife
Refrigerator
Laser pointers
Small flashlights
Black electrical tape

Optional: variety of lenses, irregular pieces of glass, different shapes and sizes of glassware filled with water

Teacher's Prep:

You will need to make the gelatin at least one day prior to the activity. Prepare the gelatin according to the package directions, using only half of the recommended amount of water. Place the gelatin in the refrigerator for several hours or overnight. Once the gelatin is set, cut out several sets of convex, concave, and rectangular lenses (see illustration). You will need one set of lenses for each group of students. During the investigation, you may want to remind the students not to eat the gelatin.

For best results, you should place strips of black electrical tape across the lenses of the flashlights to create narrow beams of light.

To Do and To Notice:

1. Give each group of students a set of gelatin lenses, a laser pointer, and a flashlight.
2. Dim the classroom lights and have the students shine the laser pointers through the convex and concave lenses and examine how the light exits each lens. Encourage them to try different angles of light entry by moving the laser up and down each lens.
3. Have the students draw and label pictures of their observations.
4. Now have the students shine the laser through either of the two shorter ends of the rectangle. Have them gently bend the rectangle and observe what happens to the light inside.
5. Have the students repeat the activity using the flashlights.
6. Ask the students what they observed. How was the light exiting the convex lens different than the light exiting the concave lens? Why do they think this is the case? What happened when they bent the rectangle lens?
7. If real lenses are available, have the students compare and contrast how light travels through these lenses versus the gelatin lenses. You can also have them observe the path of light through glass containers filled with water or irregular-shaped glass fragments.

In the Film:

As Dave enters the Cassini spacecraft he encounters glass slabs that act as huge video screens showing various visible, infrared and radar images of Saturn and its moons. As he converses with Gal 2000, we see various sensors on the ship, including the Visual and Infrared Mapping Spectrometer, the Composite Infrared Spectrometer, and the Imaging Science Subsystem.

What's Going On:

Light bends when it moves at an angle from one transparent substance to another. This bending of light is called refraction. The substances that light can move through are called mediums. Water, glass, and air are all examples of mediums. Light refracts at different angles depending on the density of the medium. For example, it refracts more when moving through glass than when moving through water because glass is denser than water.

A lens is simply a carefully ground or molded piece of transparent material that refracts light rays in such a way as to form an image. Lenses can be thought of as a series of tiny refracting prisms, each of which refracts light to produce its own image. When these prisms act together they produce a bright image focused at a point.

There are many different types of lenses which differ from one another in their shape and the materials from which they are made. A concave lens is thicker at the edges than it is at the center while a convex lens is thicker in the middle and thinner at its edges. When light enters a convex lens, the light rays converge (bend) together until they meet at a single point. They then crisscross and spread out again. In a concave lens, the light rays spread out, never converging to a single spot.

The strength of a lens depends of its shape and the material that it is made of. Optical engineers, such as those employed by NASA, often layer simple lenses in order to advance the technology of devices like telescopes, binoculars, microscopes, and cameras.

Background

Optics have a long history in astronomy and space exploration. Galileo (1564-1642) was one of the first people to use a small telescope to look at the Moon and other objects in the night sky. Since then, better ground based telescopes and special optical instruments, such as spectrometers, have enabled scientists to discover many secrets of the Universe.

Optics have also played an important role in the Space Age, beginning with the telescopes that were used to track early rocket launches. Soon after, satellites equipped with cameras, telescopes, and other optical instruments were launched to observe Earth and the surrounding planets and stars. Today, the United Sates has launched many spacecraft out of Earth's orbit to visit the planets in our solar system.

The Cassini spacecraft, which was launched on June 30, 2004 to study Saturn, is loaded with several optical instruments, including cameras, telescopes, spectrometers, and spectrographs. These instruments use various types of lenses to collect their data.

The Imaging Science Subsystem (ISS) on Cassini consists of a wide-angle camera and a narrow-angle camera.

The narrow-angle camera provides high resolution images of targets of interest, while the wide-angle camera allows more extended spatial coverage at lower resolution.

The Composite Infrared Spectrometer (CIRS) is a spectrometer that is sensitive to invisible heat rays, or infrared light. It measures the strength of the different colors, or wavelengths of heat rays, given off by a planet. CIRS splits light into different colors, like a glass prism, or a raindrop creating a rainbow.

The Ultraviolet Imaging Spectrograph (UVIS) is a box of four telescopes that can see ultraviolet light, which is invisible to the human eye. The instrument measures the views in ultraviolet light, and then scientists use these measurements to produce pictures we can see.

The Visual and Infrared Mapping Spectrometer (VIMS) is made up of two cameras. One camera is used to measure visible wavelengths, while the other measures infrared. Combined, the two cameras gather a lot of information on the composition of moon surfaces, the rings, and the atmospheres of Saturn and Titan.

Taking it Further:

Have the students layer the lenses to manipulate light in many ways. Try cutting more complex lens shapes (see illustration) and have the students explore what happens when they shine the light through them.

Did you Know:
Cassini's observations of Saturn's largest moon, Titan, have given scientists a glimpse of what Earth might have been like before life evolved. They now believe Titan possesses many parallels to Earth, including lakes, rivers, channels, dunes, rain, snow, clouds, mountains and possibly volcanoes.

Keywords:

Convex – Curving or bulging outward.
Concave – Curving inward.
Refraction – The bending of light as it passes from one substance to another.
Lens – A transparent optical device used to converge or diverge transmitted light and to form images.

Activity 6

Getting a Peek at Titan

Grades: 6-8

Objective:

Students use remote sensing techniques to analyze topographic features and then create maps based on the data they collect.

Materials:

Shoeboxes with lids
Green floral foam
(enough to cover the bottom of each shoebox)
Large spoons (tablespoons or serving spoons work well)
Nails (for punching holes in the box lids)
Coffee stirrers or wooden skewers
(approximately five inches long)
Rulers
Tape
3 X 5 index cards
Graph paper
Scissors

Teacher's Prep:

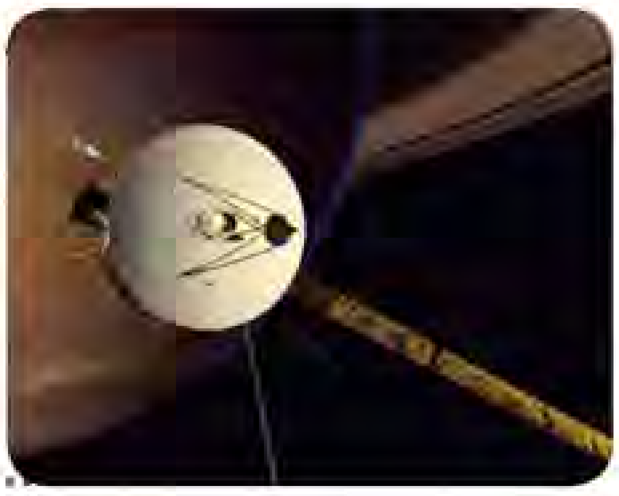
You can purchase floral foam at most craft stores. Some florists may be willing to donate scrap pieces of foam. If floral foam is not available, you can substitute moist sand and rocks.

To Do and To Notice:

1. Show the students some examples of contour maps. Discuss how scientists use these maps. Ask the students if they think it would be possible to construct a similar map of the topography of a planet or moon.
2. Divide students into groups and give each group a shoebox, spoon, floral foam, stirrer, nail, ruler, index card, tape and graph paper.
3. Have the groups of students shape the floral foam into irregular patterns. They can use the spoon to create hills and valleys.
4. When they have finished shaping the foam, have the students place the tops on their boxes.
5. Next, the students should cut a piece of graph paper to fit the top of the lid and secure it with tape.
6. Show the students how to use a nail to poke holes at each intersection of the grid on the paper. The holes should be large enough for the coffee stirrer or skewer to fit through.
7. At this point, each group of students should trade boxes with another group in the class.
8. Before the students take measurements, they will need to prepare their depth gauges.
9. Tell the students to pick any random hole in the graph paper-covered lid and insert the stirrer until it hits the bottom. They should place an index card next to the stirrer and mark where the top of the stirrer is on the card. This arbitrary height will represent sea level, so the students should mark this line as zero.
10. Beginning with the zero mark, have the students measure off and mark 0.5-centimeter increments on the index card through 10-centimeters up and down from the zero mark.
11. Have the students insert their depth gauges at the different intersections across the box lid. They should measure the height on the depth gauge at each intersection and then record this information on their individual pieces of graph paper.
12. When the students have completed all of their measurements, have them construct contour maps by drawing lines (curving if necessary) to connect all the points of equal elevation. Have them round up their measurements to the nearest whole number. (Mapmakers typically pick contour intervals that best reflect the surface being studied. For this exercise, try an interval of one or two centimeters.)
13. When the students have completed their maps, have them remove the lids from their boxes and compare their maps to the actual landscape. Do their maps accurately reflect the hills and valleys in the boxes?

In the Film:

At the beginning of the film the Cassini spacecraft zooms across the ring plane of Saturn as Casey Kasem announces that the Huygens probe will soon enter the thick cloud that surrounds Titan, Saturn's largest moon. We learn that scientists are anxious to uncover the secrets of this fascinating moon. In addition to the Huygens probe, scientists analyze the topographic features of Titan using radar data from sensors aboard Cassini.



What's Going On:

Radar works by emitting a signal to the ground and measuring the time it takes to return to the spacecraft. These measurements allow scientists to calculate the altitude of surface features on the ground regardless of the amount of cloud cover.

Cassini's radar projects pulses of radar energy toward Titan to strike the surface and echo back to the instrument. The amount of energy received by the instrument dictates how bright the resulting image is, and is a function of the type of surface being measured. The round trip travel time of each energy pulse determines the location of the echoing surface. This technique, called synthetic aperture radar (SAR), is especially useful for capturing images that are shrouded in clouds.

Raw radar data are just sets of numbers registered by digital equipment. Converting raw data into an image requires computer software that converts ranges of radiation values into colors we can see.

Background

Titan is the largest moon of the planet Saturn, and the second largest moon in our Solar System. With a diameter of 5,150 km (3,200 miles), it is approximately the same distance across as the United States. Titan is also the only moon in the Solar System that has a thick atmosphere. Unfortunately, this thick, nitrogen-rich atmosphere prevented earlier spacecraft from getting a clear view of the moon's surface. When the two Voyager spacecraft imaged Titan during flybys in 1980 and 1981, scientists saw only haze and the tops of clouds. Luckily, the Cassini spacecraft is equipped with radar. Unlike a photographic camera that needs an outside light source, radar provides its own illumination. Scientists have been able to use the radar data to understand more about the topography of Titan.

Did you Know:

The atmosphere of Titan is made mostly of nitrogen (80-90%), just like the Earth's atmosphere. Titan is the only other place in the solar system with an atmosphere so similar to Earth's. However, Titan's atmosphere is very dense, and the air pressure at the surface is even higher than Earth's atmospheric pressure.

Taking it Further:

Ask the students how their maps might differ if they used a finer grid of graph paper or a depth gauge with smaller increments. Have them repeat the activity changing one of these variables.

Download the Solar Safari Activity Guide:

www.QQtheMovie.com/#/education/planetary-guide

Keywords:

Contour Map – A map that shows the configuration of a surface by means of contour lines drawn at regular intervals of elevation above a reference level.

Radar – A method of detecting distant objects and determining their position, velocity, or other characteristics by analysis of very high frequency radio waves reflected from their surfaces.

Relief – The elevations or inequalities of a land surface.

Topography – The configuration of a surface including its relief and the position of its natural and man-made features.

Acknowledgments:
Jet Propulsion Laboratory (http://saturn.jpl.nasa.gov/)

Activity 7

Planetary Poles

Grades: 9-12

Objective:

Students will design model planets and then use magnetic compasses to infer the orientation of the magnetic fields in these planets.

Materials:

Paper grocery bag
D-size battery
Two ceramic donut magnets
Masking tape
3 large rubber bands (size 64 works well)
Permanent marker
Compass
Small bar magnet
String

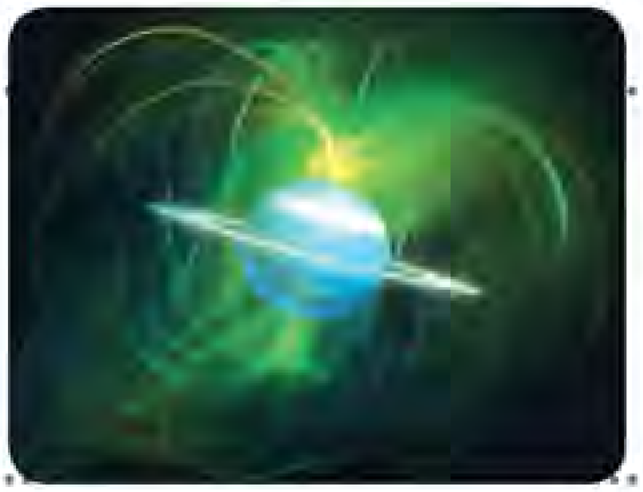
Teacher's Prep:

You can use dead batteries for this activity. Many local recycling centers will be happy to give you a bag of used batteries. The donut magnets required for this activity have definite north and south poles. These inexpensive magnets can be found at electronic stores throughout the country.

This activity works best if students work in groups of two to four.

To Do and To Notice:

1. First, have the students create a dipolar magnet that will go inside their planets. They should take the two magnets and place them on top of each other so that the magnets are attracted to each other. Now, without flipping either magnet over, have them place the top magnet on the top of the battery and tape it in place. They will then place the bottom magnet on the bottom of the battery and tape this magnet in place.
2. If the paper bags have a lot of printing or pictures on them, have the students carefully turn the bags inside out.
3. Next, have the students place their batteries inside the paper bags. (It does not matter which way the battery is facing.) They should work the paper bag around the battery to create a smooth and fairly round planet.
4. Now have the students place the first rubber band around their planets. This rubber band can be placed wherever it's most needed to hold their planets together.
5. Now have them stretch a second rubber band across their planets. This rubber band should meet at right angles with the first rubber band so that each planet is split into four equal segments.
6. Next, have the students add the third rubber band to their planets. This rubber band should stretch across both of the other rubber bands meeting those rubber bands again at right angles. The planets should now be divided into eight segments.
7. Have the students choose one of the rubber bands to represent the equator of their planets. They should use the markers to label this rubber band "equator."
8. Have the students choose a name for their planets. They can write their names on pieces of tape and then attach them to the planets.
9. At this point, the students should trade planets with another group.
10. The students should write the name of this new planet on a sheet of paper. Later, they will sketch a picture of the planet and label its magnetic poles.
11. Have the students place their compasses on the edges of their desks.
12. Have them hold their planets near the compasses so that the compasses are located near each planet's equator.
13. Each group should rotate their planet slowly about its axis while observing the effect on the compass.
14. Next, have the students experiment with holding the planets above and below the compasses while they rotate them. How does this affect the compasses? Do the compasses behave differently?
15. Finally, have the students tie a piece of string to a bar magnet and hold it near the planet. Have them slowly move the magnet around the planet and observe what happens to the magnet.
16. Based on the information they obtained from the compasses and the suspended bar magnets, have the students predict the locations of the north and south magnetic poles of their planets. They should draw a picture of the planet on their papers and label the locations of the poles.
17. Have the students continue to exchange planets and repeat steps #10–16.



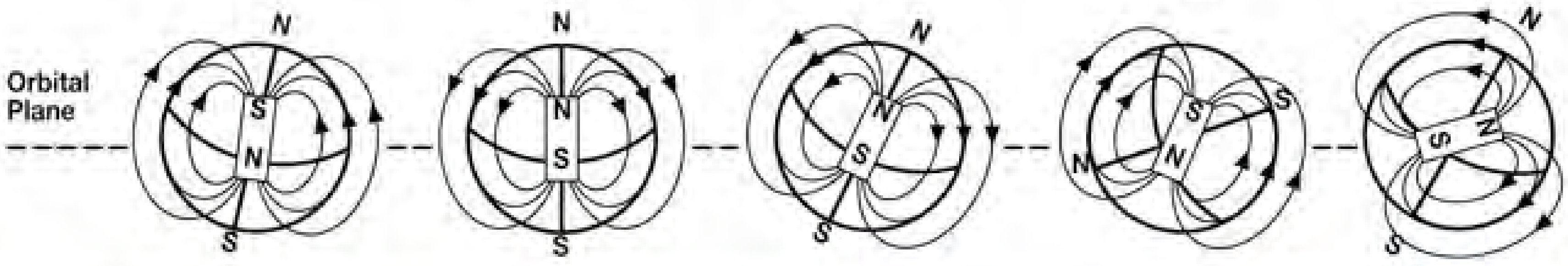
In the Film:

As Dave and the proton surfers approach Saturn they are awed by its magnetosphere. Jammer warns the others that the magnetosphere is really powerful. He tells them not to get caught on the inside or they will get pulled into its dark side.

What's Going On:

Earth, Jupiter, Saturn, Uranus, and Neptune all have magnetic fields that can be described as offset tilted dipoles. A "dipole" describes a system having two polarities such as the north and south poles of a bar magnet. "Tilted" refers to the alignment of the dipole with respect to rotation axis of the planet. In other words, how well the positions of the magnetic poles match the positions of the geographic poles. "Offset" describes the position of the dipole relative to the center of the planet. The center of the dipole may be shifted away from the planet's center both outward from the center and toward one of the geographic poles.

The magnetic fields surrounding the Earth, Mercury, Jupiter and Saturn are considered global magnetic fields. Electrical currents in Earth's core generate its magnetic field. The core consists of iron and nickel, which are good conductors of electricity. Mercury also has an iron core, which produces its field. In contrast, the magnetic fields of Saturn and Jupiter result from the flow of electricity in the liquid metal hydrogen surrounding their cores. The magnetic fields of Uranus and Neptune are generated by current flow in slushy, salty water inside these frozen gas giants.



Background

The **interiors** of planets are difficult to study. However, scientists have been able to infer many details about the interior conditions of planets through laboratory experiments, theoretical studies, and external observations. One external observation that is directly related to the conditions in the core of a planet is the shape and orientation of the planetary magnetic field. Many spacecraft, including Cassini, carry instruments called magnetometers to measure the field strength and direction of planetary magnetic fields.

Planetologists believe that planetary magnetic fields are generated by a dynamo effect within the core of a planet. The dynamo effect occurs when moving electrical charges generate magnetic fields. Such processes are believed to occur deep inside some planets.

Taking it Further:

Discuss the idea of a magnetic reversal of the Earth's poles. Have the students read the science fiction stories located at: http://image.gsfc.nasa.gov/poetry/venus/Reversal.html and then write their own stories describing the effects of a magnetic reversal.

Did you Know:
Our Moon lacks a magnetic field, which implies its interior is cold and inactive. However, rocks from the Moon show permanent magnetism, suggesting that at one time the Moon had a magnetic field.

Keywords:

Dipole – A system having two polarities, such as the north and south poles of a bar magnet.
Magnetic field – The lines of force surrounding a permanent magnet or a moving charged particle.
Magnetometer – An instrument for measuring the magnitude and direction of a magnetic field.
Magnetosphere – The region of space in which a planet's magnetic field dominates that of the solar wind.

Acknowledgments:
UCAR Windows to the Universe: www.windows.ucar.edu/windows.html — Jet Propulsion Laboratory: saturn.jpl.nasa.gov

Activity 8
Pie Pan Convection

Grades: 9-12

Objective:
Students will investigate examples of convection currents and compare them to convection cells in the Sun.

Materials:
Aluminum pie pan

4 film canisters
(or small blocks of wood five to six cm high)

2-4 tea light candles

3 tablespoons of liquid hand soap or shampoo with a pearly or metallic appearance. (Look for glycol stearate, glycol distearate, or glycerol stearate among the list of ingredients.)

Food coloring

Water

Spoon or craft stick (for stirring)

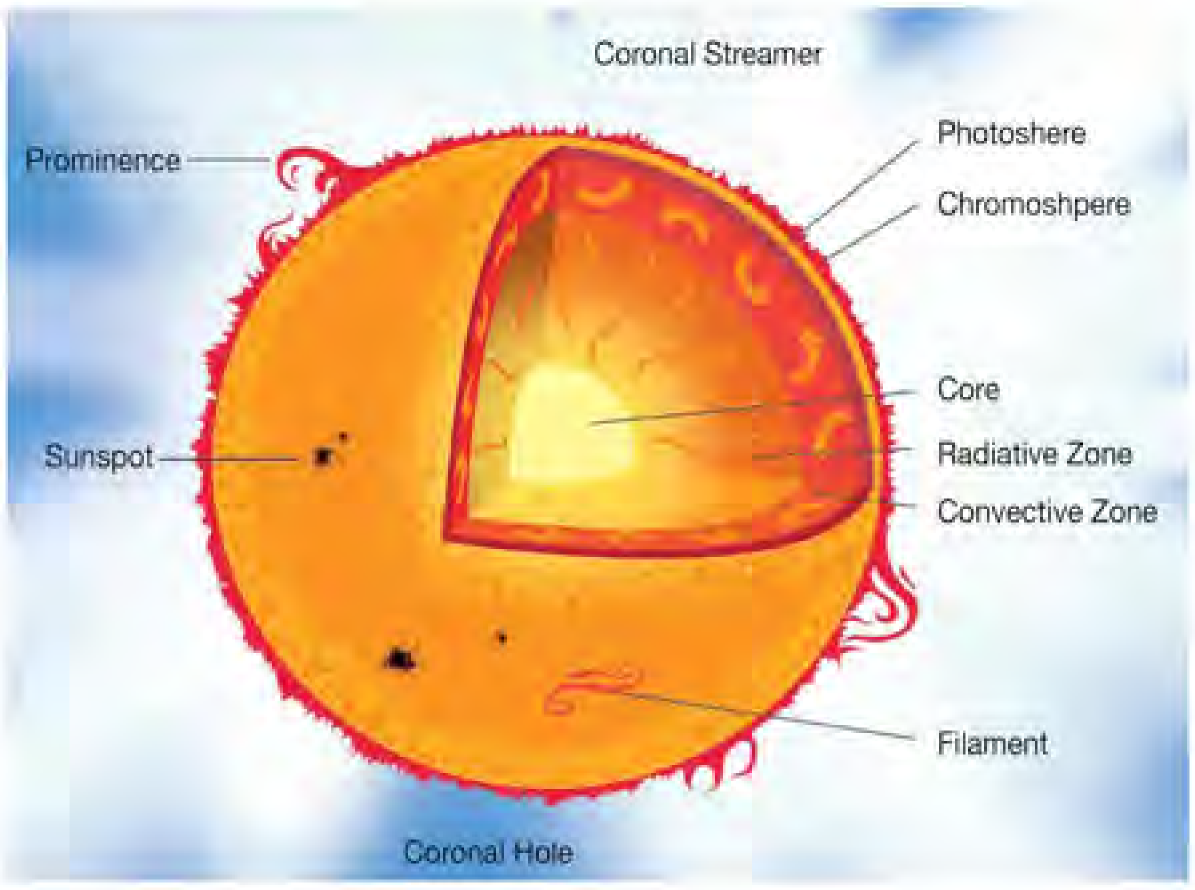
Matches or lighter

Lava lamp (optional)

Teacher's Prep:
If available, you may substitute hot plates for the tea light candles. **Softsoap® brand liquid hand soap works great for this activity.**

To Do and To Notice:

1. Have the students fill their pie pans approximately 1/2 to 3/4 full with water.
2. Have them spread out the four film canisters on their tables and place their pie pans on top of canisters.
3. Now have the students squeeze approximately three tablespoons of soap into the water. They should gently stir the soap and water, being careful not to create any bubbles.
4. Next, have the students add several drops of food coloring to the soapy water and stir.
5. Have the students light their candles and slip them under the center of their pans.
6. Give the students several minutes to observe the convection currents. If time permits, allow them to walk around to observe the results of other groups.
7. After awhile, have the students remove the pans from the candle flames and place them on a flat cool surface. Ask them to wait and observe what happens as the soapy water cools.



8. Have the students view some of the images or animations of the Sun from NASA websites. (See the "Resources" section on the next page.) In what ways is the pie pan convection activity similar to these images? How is it different?
9. If possible, bring in a lava lamp for the students to observe. Ask them to explain the movement of the wax in the lamp using what they know about convection.

In the Film:
Near the beginning of the film we view live images of the Sun from the SOHO mission, revealing huge prominences bursting into space. We also dive through a sunspot and pass through the chromosphere and photosphere of the Sun until we get to the core.

What's Going On:

The soap solution at the bottom of the pan heats up and becomes less dense. This lighter liquid rises in localized columns. When the warm fluid reaches the surface, it cools, becomes heavier and sinks. The region where the fluid rises and sinks is called a convection cell. When the pan is on the candles, convection cells rise directly above the flame. When the pan is moved to the flat cool surface, the convection process slows. This allows convection cells to widen and become well defined.

Convection takes place in many other systems. A pot of water boiling on the stove is a good example of convection. When spaghetti is boiled in a large pot, the noodles rise near the middle of the pot above the flames, spread out over the surface, and then fall again near the edges where it is cooler. In the Earth's atmosphere, convection results in regional weather patterns and thermals (rising columns of heated air).

Background

Convection is the transport of energy due to density differences in a liquid or gas. As a liquid or gas is heated, it expands and becomes lighter and less dense. If a cooler, denser material is above the hotter layer, the warmer material will rise through the cooler material to the surface. The rising material will dissipate its heat (energy) into the surrounding environment, causing it to cool and become denser. This denser material will sink and the process will start over again.

Convection is one way that energy is transferred in the interior of the Sun. The energy from the fusion reactions occurring in the Sun's core moves outward in the form of electromagnetic radiation, called photons, into the radiative zone. The energy then moves upward in photon-heated solar gas. This hot gas from the radiative zone expands and rises through the cooler, less dense convective zone. It then cools and begins to sink again. As it falls down to the top of the radiative zone, it heats up and starts to rise. This process repeats, creating convection currents and the visual effect of boiling on the Sun's surface. This boiling effect is called granulation, and results from viewing the top of the convection cells coming from the convective region below. The bright centers of the granules represent the rising hot gas, while the darker "rings" are the sinking cool gas.

Convection motions within the solar interior generate magnetic fields that emerge at the surface as sunspots and loops of hot gas called prominences. Most solar energy finally escapes from a thin layer of the Sun's atmosphere called the photosphere, which is the part of the Sun observable to the naked eye.

Taking it Further:

Have the students repeat the activity using a denser material, such as dark corn syrup or chocolate syrup, for the food coloring. Ask them to predict how their results might differ from the original investigation.

Resources:

http://sohowww.nascom.nasa.gov/gallery/images.html
http://www.nasa.gov/mission_pages/solar-b/solar_013.html
http://solarb.msfc.nasa.gov/index.html

Did you Know:
A sunspot has a temperature of nearly 4000 degrees Celsius. It would appear brighter than the full moon if placed in the night sky.

Explore More! SOHO Space Mission:

http://www.qqthemovie.com/soho-mission/

Keywords:

Convection – The process through which heat energy is transferred through currents within a liquid or gas.
Granulation – The small, transient, brilliant granular markings on the photosphere of the sun.
Photosphere – The luminous surface layer of the sun.
Prominences – Sheets of luminous gas emanating from the sun's surface.
Sunspots – Any of the relatively cool dark spots appearing periodically in groups on the surface of the sun, which are associated with strong magnetic fields.

Acknowledgments:
Exploratorium: www.exploratorium.edu/snacks — NASA: sohowww.nascom.nasa.gov

Activity 9

Sizing up the Sun

Grades: 9-12

Objective:

Students will design a pinhole viewer and devise a method for measuring the diameter of the Sun.

Materials:

Pieces of cardboard or file folders (approximately 4" X 6")

Aluminum foil

White paper

Thumb tacks or straight pins

Tape

Scissors

Rulers or meter sticks

Graph paper

Miscellaneous materials for creating pinhole viewers (index cards, file folders, scrap pieces of cardboard, cardboard tubes, shoeboxes)

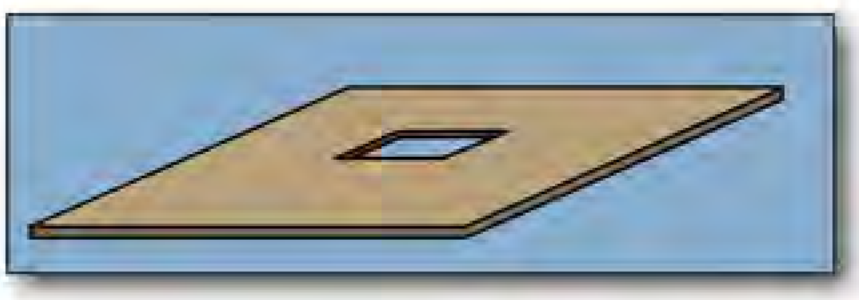
Access to Internet

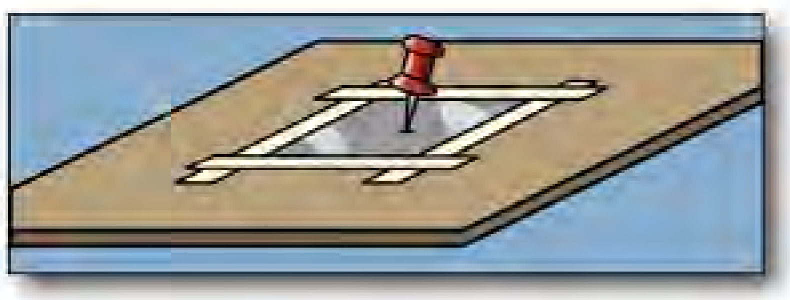
Teacher's Prep:

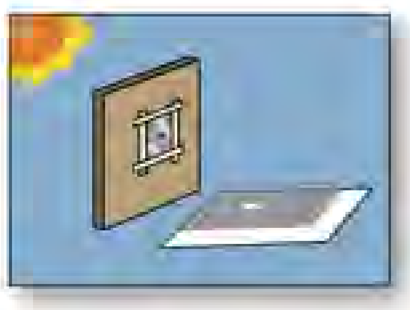
This activity will need to be conducted on a sunny day. If necessary, it can be divided over two or more class periods. The students will begin the lesson by building simple pinhole viewers to observe the Sun. They will then devise methods for improving these viewers and using them to measure the Sun's diameter.

To Do and To Notice:

1. Each group of students will need a piece of cardboard, a thumb tack, scissors, aluminum foil, a sheet of white paper, and tape.
2. Have the students cut a 2 cm X 2 cm hole in the center of the cardboard.
3. Next, they will cut a piece of aluminum foil that is slightly larger than the hole.
4. Have the students lay the foil over the hole and tape it down.
5. Now, have them use their tacks to carefully poke a tiny hole in the center of the aluminum foil.
6. Have the students take their pinhole viewers and their sheets of white paper outside.
7. They should hold the pinhole up to the Sun so that light from the Sun passes through the hole and falls on the white sheet of paper. They should experiment with the distance between the pinhole and the white paper. (Larger distances work better.)
8. Once all of the groups have successfully cast an image of the Sun onto the paper, return to the classroom.
9. Ask the students how they might be able to use their pinhole viewers to measure the diameter of the sun.
10. Show the students the triangle formula (See page 20) the diameter of the Sun(D) & the distance to Sun(L) equals the diameter of the Image(d) & the distance to the Image(l) Explain that the estimate of solar diameter is based on the idea of similar triangles. In this case, the two triangles are the one formed by the solar image with the pinhole and the one formed by the Sun and the pinhole. The analysis of these similar triangles says that the ratio of the diameters to the distances is equal.
11. Ask the students how they could use the above information to determine the diameter of the Sun. What information would they need? How could they find this information? If students are having difficulty, prompt them with further questions. Can they find the distance to the Sun? Can they measure the diameter of the projected image? How?
12. Show the students the available supplies (rulers, graph paper, meter sticks, poster board, etc.) and ask them to think about how they might use these materials to improve their pinhole viewer and then measure the diameter of the Sun. Provide access to the Internet or other resources for students to find the distance between the Sun and the Earth.
13. Allow students time to come up with a plan and test their ideas. Remind them to take several measurements and average their results.
14. When the students have completed the activity, have them compare their results to the actual diameter of the Sun. They can calculate the percentage difference between their results and the official value.
15. Have each group of students prepare a report or presentation about their device and their results to share with the rest of the class.







In the Film:

As Rayna races across the solar system to deliver her message she encounters the Gell-Man ghosts who tear apart her rocket sled. She is forced to steer her tattered sled towards the Sun, where she reunites with Dave. The Sun appears enormous as Rayna rockets toward its surface. In fact, it is only an average star – there are many stars in the universe that are much larger.

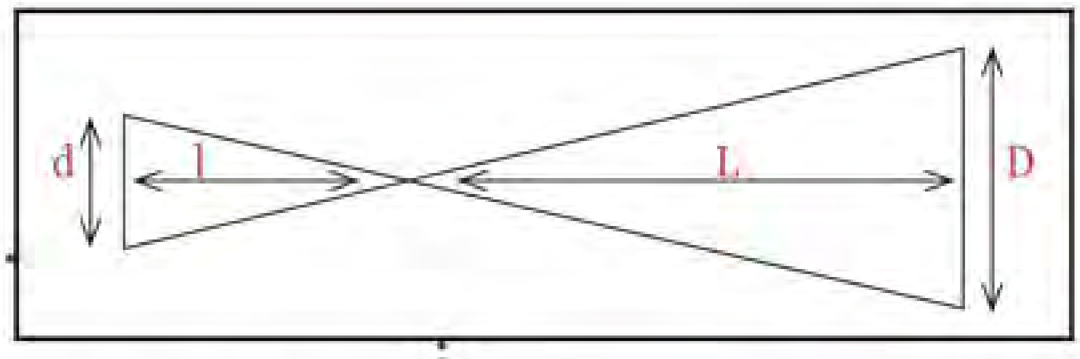
What's Going On:

The simplest way to understand pinhole images is to imagine what happens to light rays radiating from an object, such as a candle flame, when observed through a pinhole viewer. Light radiates from all parts of the flame, and bounces off the candle body. However, the pinhole lets through only a portion of these light rays – the surrounding cardboard blocks the rest. Only a few of the rays of light from the flame or candle are heading in just the right direction to shine through the pinhole of the viewer. Light rays from the top of the flame must slope down to pass through the pinhole. These rays hit the bottom of the screen. Similarly, rays of light from the base of the flame or the candle must slope up to pass through the pinhole. These upward moving rays will hit the top of the screen. Because the rays from the top of the flame hit the bottom of the screen, and the rays from the bottom of the flame hit the top of the screen, the image of the flame appears upside-down on the screen.

Background

The Sun is enormous compared to other objects in the solar system. It is so massive that it accounts for 99.9% of all of the matter in the solar system. In fact, the Sun is so big that if it were hollow, it could hold over one million Earths.

The Sun's diameter is measured by first taking angular diameter measurements and then translating them to linear diameter measurements. The angular diameter of the Sun, or more precisely of the photosphere, can be measured by using telescopes, especially during total solar eclipses or by timing Mercury when it is in transit in front of the Sun. Jean Picard in Paris, France took the first series measurements of the Sun in the early 1700's.



Taking it Further:

Challenge the students to determine whether or not they could use their pinhole viewers to calculate the diameter of the moon. What information would they need to collect? How would they determine the best day to make the measurements? Have each group come up with a plan.

Keywords:

Diameter – The length of a straight line passing through the center of a circle and connecting two points on the circumference.

Angular diameter – The angle that the apparent diameter of a celestial object subtends at the eye of the observer.

Did you Know:

The Sun is big, but it doesn't hold a candle to some of the largest stars in the Universe. The biggest star discovered to date is called Canis Majoris, and astronomers think it could be 2,100 times the size of the Sun.

The Solar System

Our Neighborhood in the Universe

Ancient astronomers observed points of light that seemed to move among the stars. They called these objects "planets," which meant wanderers, and named them after Roman deities – Jupiter, king of the gods; Mars, the god of war; Venus, the goddess of love; Mercury, the messenger of the gods, and Saturn, father of Jupiter and god of agriculture.

With the invention of the telescope, three more planets were discovered. Uranus in 1781, Neptune in 1846, and Pluto (now downgraded to a dwarf planet) in 1930.

The planets farthest from the sun are called gas giants, while those closest to the sun are the terrestrial planets. (Pluto, the tiniest and most distant has a solid but icier surface than the terrestrials.)

Each planet is unique in its features. Some are visually spectacular with their ring systems and orbiting moons.

Because Saturn is tilted, when its rings are facing Earth edge-on they disappear from our view. We now know this happens every 14 years or so, but 16th century scientist Galileo Galilei questioned his sanity when they "disappeared" and then "reappeared" a few years later. — NASA

The Sun

The Sun is the center of our Solar System. Although a fairly ordinary star, it has inspired stories from many cultures around the world. Many ancient cultures built stone structures or formations to observe the Sun. Ancient Egyptians, Aztecs of Mexico, Native Americans and many others charted the seasons, created calendars and kept track of solar eclipses.

The Sun is a huge sphere of mostly ionized gas, and is the closest star to the Earth. It supports life on our planet and is intimately connected with seasons, ocean currents, climate and weather.

To explore more about the Sun, take the Quantum Quest Space Mission at: www.QuantumQuest.com/soho-mission

The Kuiper Belt

The Kuiper Belt, our Solar System's "final frontier," is a disk-shaped region of icy debris about 4.5-7.5 billion km (2.8 billion to 4.6 billion miles), or 30-50 Astronomical Units (AU) from our Sun. Its existence was confirmed only a decade ago; the collection of icy objects, KBO's, are an emerging area of research in planetary science. No spacecraft has ever traveled to the Kuiper Belt, but NASA's New Horizons mission, which is scheduled to arrive at Pluto in 2015, might be able to reach farther into the Belt to study these mysterious objects.

NASA's Unmanned Space Missions

Cassini Equinox Mission

The Cassini spacecraft was named after Jean-Domenique Cassini who discovered the Saturnian satellites Lapetus in 1671, Rhea in 1672, and Tethys and Dione in 1684. In 1675, he discovered what is known today as the "Cassini Division," the narrow gap separating Saturn's rings in two parts.

The Huygens probe was named in honor of Christiaan Huygens, who discovered Titan in 1655. This probe was the first landing of a craft on a body in the outer Solar System.

Cassini completed its initial four-year mission to explore the Saturn System in June, 2008. Now the healthy spacecraft is working overtime on the Cassini Equinox Mission to seek answers to new questions raised in Cassini's first year at Saturn. The mission's extension, through September 2010 is named for the Saturnian equinox, which occurs in August 2009 when the sun will shine directly on the equator and begin to illuminate the northern hemisphere and the rings' northern face.

Cassini has revealed that Saturn's largest moon, Titan, is one of the most Earth-like worlds in the Solar System. With its thick atmosphere and organic-rich chemistry, Titan resembles a frozen version of our planet, several billion years ago.

SOHO Mission (Solar and Heliospheric Observatory) is an international collaborative project between NASA and ESA (European Space Agency) to study the Sun from its deep core to the outer corona and the solar wind.

SOHO was launched on December 2, 1995. The spacecraft was built in Europe under ESA. Twelve instruments on board were provided by both American and European scientists.

Some of the key results:

- The first images ever of a star's convection zone (its turbulent outer shell) and of the structure of sunspots below the surface.
- Most detailed and precise measurements of the temperature structure, the interior rotation and gas flows in the solar interior.
- Discovering new dynamic solar phenomena such as coronal waves and solar tornadoes.

Mercury

Average distance from Sun	57,909,175 km (35,983,095 miles)
Diameter	4879.4 km (3031.92 miles), about 33% of the diameter of Earth.
Surface gravity (Earth=1)	0.38
Length of day (in Earth days)	58.65 days
Length of year (in Earth days)	87.97 days
Number of moons	None
Atmosphere	Trace amounts of hydrogen and helium.
Average surface temperature	179°C (354°F)
Interesting fact	Mercury is only slightly larger than the Earth's moon.

Venus

Average distance from Sun	108,208,930 km (67,237,912 miles)
Diameter	12,104 km (7,521 miles), about 95% of the diameter of Earth.
Surface gravity (Earth=1)	0.91
Length of day (in Earth days)	243 days
Length of year (in Earth days)	224.7 days
Number of moons	None
Atmosphere	Carbon dioxide and nitrogen.
Average surface temperature	452°C (870°F)
Interesting fact	Venus rotates clockwise, while the other planets rotate counterclockwise.

Earth

Average distance from Sun	149,597,890 km (92,955,819 miles)
Diameter	12,756 km (7,926 miles)
Surface gravity (Earth=1)	1
Length of day (in Earth days)	1 days
Length of year (in Earth days)	365 days
Number of moons	1
Atmosphere	Nitrogen and oxygen.
Average surface temperature	15°C (59°F)
Interesting fact	Earth is the fifth largest planet in the solar system (after Jupiter, Saturn, Uranus and Neptune).

Mars

Average distance from Sun	227,936,640 km (141,633,262 miles)
Diameter	6,787 km (4,217 miles), about 53% of the diameter of Earth.
Surface gravity (Earth=1)	0.38
Length of day (in Earth days)	1.03 days
Length of year (in Earth days)	686.93 days (1.9 Earth years)
Number of moons	None
Atmosphere	Carbon dioxide, nitrogen and argon.
Average surface temperature	-63 °C (-81 °F)
Interesting fact	Olympus Mons, the largest volcano on Mars, is 17 miles (27 km) tall and over 320 miles (520 km) across.

Jupiter

Average distance from Sun	778,412,020 km (483,682,805 miles)
Diameter	142,800 km (88,700 miles), more than 11 x's the diameter of Earth.
Surface gravity (Earth=1)	2.36
Length of day (in Earth days)	0.41 days (9.8 Earth hours)
Length of year (in Earth days)	4,332 days (11.86 Earth years)
Number of moons	62
Atmosphere	Hydrogen, helium and methane.
Average surface temperature	-153°C (-244°F)
Interesting fact	Jupiter is so big that all the other planets in our Solar System could fit inside it.

Explore More! Download the Planetary Activity Guide:
www.QQtheMovie.com/#/education/planetary-guide

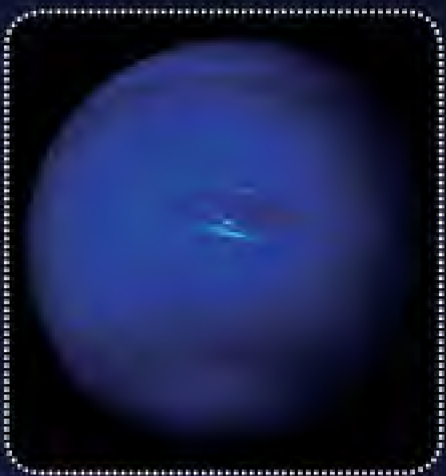
Saturn

Average distance from Sun	1,426,725,400 km (886,526,063)
Diameter	120,660 km (74,975 miles), about 9.4 times the diameter of Earth
Surface gravity (Earth=1)	0.92
Length of day (in Earth days)	0.44 days (10.5 Earth hours)
Length of year (in Earth days)	10,761 days (29.46 Earth years)
Number of moons	61
Atmosphere	hydrogen, helium, methane
Average surface temperature	-185° C (-290° F)
Interesting fact	Saturn is the only planet in our Solar System that is less dense than water.

Uranus

Average distance from Sun	2,870,972,200 km (783,939,419 miles)
Diameter	120,660 km (74,975 miles), about 9.4 times the diameter of Earth
Surface gravity (Earth=1)	0.89
Length of day (in Earth days)	0.72 days (17.23 Earth hours)
Length of year (in Earth days)	30,685 days (84 Earth years)
Number of moons	27
Atmosphere	hydrogen, helium, methane
Average surface temperature	-212°C (-350°F)
Interesting fact	Uranus' blue color is caused by the methane (CH_4) in its atmosphere.

Neptune



Average distance from Sun	4,498,252,900 km (2,795,084,767 miles)
Diameter	49,528 km (30,775 miles), about 3.88 times the diameter of Earth
Surface gravity (Earth=1)	1.12
Length of day (in Earth days)	0.67 days (16.1 Earth hours)
Length of year (in Earth days)	60,190 days (164.8 Earth years)
Number of moons	13
Atmosphere	hydrogen, helium, methane
Average surface temperature	-225°C (-373°F)
Interesting fact	The magnetic field of Neptune is about 27 times more powerful than that of Earth.

References

www.astrogeology.usgs.gov/Research/RemoteSensing - Information about remote sensing by Cassini-Huygens mission and other astrogeology projects.

www.windows.ucar.edu - K-12 classroom projects and general space science information.

www.science.nationalgeographic.com/science/space/solar-system - General information about the solar system, interactive images, and related articles.

www.science.nationalgeographic.com/science/space/solar-system - Links to current solar system missions as well as detailed information about individual planets.

www.saturn.jpl.nasa.gov/ - Homepage for NASA's Cassini mission.

www.sungazer.net/index.html - Images of the Sun, podcasts, and descriptions of solar viewing equipment.

www.solar-center.stanford.edu/ - Many resources related to the Sun and solar energy, including K-12 lesson plans, solar folklore, online activities and solar art.

www.coolcosmos.ipac.caltech.edu/ - Activities, videos, and other classroom resources related to infrared light.

www.sohowww.nascom.nasa.gov/ - Homepage for NASA's SOHO (Solar and Heliospheric Observatory) mission.

www.spacegrant.hawaii.edu/ - More than 25 hands-on activities for exploring Earth, planets and space science.

www.spaceplace.jpl.nasa.gov/en/kids/ - NASA site for K-6 students with activities, projects, and games related to deep space missions

www.spaceweather.com/ - Information and activities exploring the Sun-Earth environment, including the solar wind and the aurora borealis.

www.michielb.nl/od95/ - An interesting tour about the sun using fascinating images and MPEG movies.

www.quest.arc.nasa.gov/ - NASA's web-based, interactive explorations designed to engage K-12 students in authentic scientific and engineering processes.

www.amazing-space.stsci.edu/resources/explorations/index.shtml - K-12 online explorations on various space related topics.

QUANTUM QUEST A CASSINI SPACE ODYSSEY 3D

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CASSINI-HUYGENS MISSION

Explore More! 8th Grade Expanded Interactive Lesson

The Cassini Equinox Mission was created to explore Saturn, its rings and its moon system. Let's take a closer look at the mission and the wonderful discoveries that have been made to date!

Start by going online to www.QQtheMovie.com
Click the Quantum Quest Space Missions button.
Now, select the Cassini Mission button:

CASSINI MISSION

Be sure to bookmark this page on your computer as this will be the starting point for all of your Cassini-Huygens activities.
[http://www.qqthemovie.com/cassini-mission/]
Click the **LAUNCH MISSION** to learn about the Cassini-Huygens Mission

Now Let's Explore More About the Mission

Let's learn more about why the mission was developed, and what has happened up to now. In the left navigation, click on EXPANDED LESSON: STEP 2. This will take you to the official NASA Cassini internet site.

- **On the QQ left navigation menu, select "EXPANDED LESSON: STEP 2" This will automatically load NASA'S "Introduction" to the Cassini Mission**

Scroll down the page and take some time at this site to learn about the goals and history of the Cassini mission.

Present Position

This mission is currently ongoing. The spacecraft is still beaming pictures and data back to earth. Let's discover its present position in the Saturn system.

- **Select the next left navigation link "Present Position."** [http://saturn.jpl.nasa.gov/mission/presentposition/]
- **Click on the 1st picture to get an enlarged view of Cassini's location in relation to Saturn.**

Where do you think the spacecraft is headed next? Why? Saturn is one of the most fascinating planets in our solar system. Its rings are an unusual phenomena that has been studied by astronomers for centuries.

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An Exploration of the Venus Express Mission

Mars Mission

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Cassini-Huygens Mission

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SOHO Mission

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The Name Game

Name these Quantum Quest Players & Reveal the Secret Phrase!

Spell each character's name in the blanks below their movie poster then copy the circled letters into their matching number blank at the bottom of this page to reveal the secret phrase!

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solve the secret phrase!

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