"From High Tech to Low Tech & Back Again"
Innovative classroom activities on Saturn and the Cassini Mission

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INTRODUCTION

Over the course of the past few years, the National Aeronautics and Space Administration (NASA) has worked to develop educational programs for students. NASA education specialists are developing a series of educational materials including inquiry-based activities, curriculum supplement materials, and reference materials that aim to introduce students to the excitement of America's space flight program. Collectively termed "education outreach," these programs develop materials for both formal classroom use as well as incorporation into informal education programs such as those at museums and science centers. The Cassini Mission is one of NASA's space flight programs with an established education program.

CASSINI MISSION EDUCATION OUTREACH

The Cassini Education Outreach Team is dedicated to creating a variety of materials for classroom use as well as informal education venues. Traditional materials such as slide sets, educator guides, posters, fact sheets, and other teaching aids have been the cornerstone of the Cassini Outreach program. The "Saturn In Your Kitchen" program is a unique addition to these traditional materials. In response to an increasing demand by classroom educators for hands-on, inquiry-based science and engineering materials, the Cassini Education Outreach Team has created "Saturn In Your Kitchen and Backyard." This series of activities are aligned with national education standards in math, science, and technology to maximize an educator's ability to incorporate them into their curriculum. With the increasing emphasis being placed on standards-based learning, this alignment is crucial to the success of the "Saturn In Your Kitchen" classroom educator who is looking for material applicable to specific standards and can easily choose from among these activities that will enhance their students' learning.

The activities demonstrated at TechEd01 expand on the "Saturn In Your Kitchen" program by integrating off-the-shelf computer software to enhance the student's learning experience.

Several companies (Vernier, Pasco, and others) now offer a variety of measurement hardware and software that can record data for later analysis. The use of appropriate probes, e.g., photometric, magnetic, thermometric, etc. allows students to actually record, quantitatively and automatically, their results. They otherwise acquire data using relative detectors like their eyes or magnetic compasses and have to write temperatures in a lab notebook (not a bad thing, as such, but not necessarily as complete, frequent, and error-free as automatic recording).

All activities in the "Saturn In Your Kitchen" program have been field-tested by educators. Many of the activities have been developed by classroom educators working with a scientist or engineer from the Cassini Mission. They are all presently written for the low tech approach, but are easily adaptable to computer-aided data acquisition.

SATURN IN YOUR KITCHEN EXAMPLES

Classroom activities cover a wide range of science, math, engineering, and liberal arts subjects. Text for the two activities presented are included below. These two examples are focused on different subjects in planetary science. To acquire additional "Saturn In Your Kitchen" activities, visit the Cassini Mission web site at http://www.jpl.nasa.gov/cassini.

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APPENDIX

Planetary Magnetic Fields – A Cassini Science Investigation

Purpose

Using three measurements with a magnetic compass, the orientation of the magnetic field in manufactured "planets" can be deduced by students-turned-planetologists.

Saturn System Technology: Saturn's Magnetosphere

Keywords: Planet, Magnet, Dipole, Magnetometer, Compass

The interiors of planets may forever remain out of the realm of direct observation and measurement. Yet, by means of laboratory experimentation, theoretical studies, and external observations, scientists can infer many details about the conditions found deep inside a planet. One external observation directly related to conditions in the core of a planet is that of the shape and orientation of the planetary magnetic field.

Spacecraft carry instruments called magnetometers to measure the field strength and direction of planetary magnetic fields. These instruments are so sensitive that they must be mounted on long booms extending from the main body of the spacecraft. Otherwise they would pick up magnetic fields generated by flowing electrical currents and permanent magnets aboard the spacecraft.

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 of a bar magnet. Tilted refers to the alignment of the dipole with respect to the rotation axis of the planet, that is, 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.

Planetologists believe that a planetary magnetic field is generated by a dynamo effect within the core of a planet. The dynamo effect describes accelerating electrical charges which generate magnetic fields. Such processes are believed to occur deep inside some planets, based on the observation of their external magnetic fields. A spacecraft like Cassini can measure these magnetic fields, including their strength and direction, at a large number of places around Saturn, from the equator to near the poles and from nearby and far away. This allows detailed characterization of Saturn's magnetic field and permits the construction, within a computer, of good models of the generating source.

In this activity students can observe the effects of a simulated planetary magnetic field and infer details about its source. The instructor can specify the complexity of the planetary field.

Materials

- bar magnets or cow magnets; must be strong (sources: bar magnets - toy store, office supply store, hardware store, or fabric store; cow magnet - veterinary or farm supply store)
- Solid rubber balls (approximately the size of a tennis ball)
- Pencils
- Magnetic compasses

Procedure

Test "planets" made from bar magnets and balls can be constructed as either demonstrators or mysteries for students to solve. The length of the magnet, compared to the diameter of the ball, may be the determining factor. At their simplest, holes can be bored in balls and magnets placed inside each, held either by friction or with rubber cement. The holes or protruding magnet ends will give away the orientation of the magnet.

Alternatively, balls whose diameters exceed the lengths of the magnets can be cut in half. A section of one (for radial offset) or both hemispheres (for no or geographic offset only) can be hollowed out. The magnet is placed in the hollow and the hemispheres are glued together again.

Make several "planets" and decide in advance on a prime meridian for each (draw a 0 degree longitude half-circle connecting the north and south geographic poles).

Construct "planets" with no offset or tilt and others with different amounts of offset, tilt, and both. More elaborate "planets" with more than one magnet can also be constructed, and have some similarity to the more complex magnetic fields of real planets. Use a pencil or dowel jammed into the geographic pole of each "planet" to mark its rotation axis and as a handhold for experiments. Each "planet" can have more than one rotation axis and prime meridian; color code and number them. Thus, each ball+magnet becomes several "planets" for experimentation.

The compass should be placed on the edge of a nonmagnetic surface (ideally, each student's desk). Students should observe the effect of slowly rotating the "planet" about its axis from at least two positions. One position should be in the plane of the equator. The other(s) should be near the pole(s). One can predict the effect of the "planet" on the compass as follows:

No offset, no tilt - From both positions the compass will point towards the "planet", with no effects visible due to rotation. A different end of the needle will point towards either pole.

Radial offset, no tilt - From both positions, the compass points towards the "planet" but rotation will cause the compass needle to be displaced a small amount in either direction from some zero-point. A different end of the needle will point towards either pole.

Axial offset, no tilt - Three measurements, at the equator and near both poles, may distinguish a geographic offset. Otherwise, the compass will point towards the "planet", with no effects visible due to rotation. Additional measurements made at a different distance may help to indicate this offset. A different end of the needle will point towards either pole.

No offset with small tilt - With an equatorial measurement, the compass will point towards the "planet", with no effects visible due to rotation. Polar measurements will show displacements with rotation. A different end of the needle will point towards either pole.

No offset with tilt near 90 degrees - The equatorial measurement shows the needle reversing direction, i.e., rotating in step with the rotation of the "planet." Polar measurements show little difference from the equator measurement.

Offset and tilt - Measurements at the equator and both poles and at two distances should be able to distinguish the degrees of offset and tilt of the internal dipole. Similar measurements of "planets" with multiple dipoles can sort out their more complex magnetic fields.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

12. Understands motion and the principles that explain it.

Level II: Upper Elementary (Grades 3-5)

- Knows that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction.
- Knows the relationship between the strength of a force and its effect on an object (e.g., the greater the force, the greater the change in motion; the more massive the object, the smaller the effect of a given force).

13. Knows the kinds of forces that exist between objects and within atoms.

Level I: Primary (Grades K-2)

- Knows that magnets can be used to make some things move without being touched.

Level II: Upper Elementary (Grades 3-5)

- Knows that magnets attract and repel each other and attract certain kinds of other materials (e.g., iron, steel).

15. Understands the nature of scientific inquiry.

Level I: Primary (Grades K-2)

- Knows that learning can come from careful observations and simple experiments.
- Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses.

Level II: Upper Elementary (Grades 3-5)

- Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.
- Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.
- Plans and conducts simple investigations (e.g., makes systematic observations, conducts simple experiments to answer questions).
- Uses simple equipment and tools to gather
- scientific data and extend the senses (e.g., ru-lers, thermometers, magnifiers, microscopes, calculators).
- Knows that good scientific explanations are based on evidence (observations) and scientific knowledge.
- Knows that scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Knows that scientists review and ask questions about the results of other scientists' work.
- Knows that different people may interpret the same set of observations differently.

Level III: Middle School/Jr. High (Grades 6-8)

- Designs and conducts a scientific investigation (e.g., formulates questions, designs and exe-cutes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures).

- Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data. Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

Level IV: High School (Grades 9-12)

- Understands the use of hypotheses in science (e.g., selecting and narrowing the focus of data, determining additional data to be gathered; guiding the interpretation of data).
- Designs and conducts scientific investigations by formulating testable hypotheses, identifying and clarifying the method, controls, and variables; organizing and displaying data; revising methods and explanations; presenting the results; and receiving critical response from others.
- Knows that a wide range of natural occurrences may be observed to discern patterns when conditions of an investigation cannot be controlled.

Scattering: Seeing the Microscopic Among the Giants – A Cassini Science Investigation

Purpose

Light waves passing through a medium are used to estimate the sizes of particles within the medium.

Saturn System Analogy: Planetary Ring Systems

Keywords: Scattering, Shadow, Obscuration, Reflection

Our everyday view of the world relies on the reflection of light from the objects around us. This reflection is called backscatter when applied to tiny objects scattering light back to an observer when the light source is behind him or her. Very tiny objects, approximately the size of the light source's wavelength, also send light forward, and do it more efficiently than they backscatter light. This light travels in approximately the same direction of travel as it came from the source. This effect, called forward scattering, is used by scientists when studying planetary atmospheres and ring systems. The scattering allows scientists to estimate the sizes of particles in those environments.

Materials

- Laser pointer
- Two large binder clips
- Two clear, plastic or glass water bottles or cups (walls should be transparent, smooth, and vertical), 50-100 mm in diameter (bottled water or soft drink bottles are good as long as they have some non-corrugated surface)
- Tap water
- Milk (1/20 teaspoon - a "pinch" per 12 oz. of water)
- Eye dropper
- Flour (less than or equal to 1/4 tsp. per 12 oz. of water)

- Turntable (Lazy Susan; optional but helpful)
- Masking, duct, or electrical tape

Procedure

Adhere a small piece of tape to one side of the container. Fill the first container with water and place it on the turntable. Prepare a highly dilute solution of milk, thoroughly mixed so the water is just slightly whitened. (Confirm the right proportions by experimentation in advance.)

For convenience, use the binder clips as legs to stand the laser, with one also holding the laser's switch in the "on" position.

Align the laser to pass through the water container so the beam projects onto the small piece of opaque tape on the far side of the water container. (The tape is to prevent the laser beam from being projected across the room into viewers' eyes.)

Darken the room, if possible. Project the laser beam through the container of plain water. The beam should pass straight through and be invisible, or nearly so, in the bottle. Next, project the beam through the dilute milk solution. Laser light scattering from tiny globules of milk will delineate the laser beam. Observe the brightness of the beam in the mixture as the turntable is rotated. The intensity of the beam is stronger or weaker according to the scattering properties of the milk particles (primarily their size) as the assembly is turned in front of fixed observers. For older students, a simple photometer can be used to compare the brightness of the beam as a function of the viewing angle. Note the strong forward scattering: the beam reaches maximum brightness when observed along nearly the direction it is coming from.

Next, mix flour with the plain water (less than or equal to 1/4 tsp flour per 12 oz of water) in the first container. Project the laser beam through the dilute flour solution. The scattering properties of the milk and flour solutions are different because there is greater variation in flour particle size than in milk globule size. Recall that store-bought milk is homogenized (its globules are reduced to the same size) so the cream stays in the solution. With either mixture, when looking perpendicular to the laser beam (i.e., from the side), notice how the beam intensity diminishes with distance traveled through the medium.

As an everyday, terrestrial example, recall that bright headlights in fog may or may not help drivers, depending on particle size. Backscatter from large fog droplets makes night visibility with bright headlights poorer than with dimmed headlights.

Additional Experiments and Questions

Try other materials that will remain suspended in liquid for useful amounts of time. Corn meal, corn starch, silt from a local stream bed, glitter, salt, and sugar will provide varying results. Try transparent carbonated beverages, including their foams, and cigarette smoke trapped in a jar. Which work? Which don't? Why? Can you detect different particle shapes based on scattering?

Is the color of the daylight sky related to sunset colors and scattering?

Because scattering is a phenomenon dependent on both the wavelength of the wave being scattered and on the size of the scatterer, much can be learned by working in well-separated parts of the electromagnetic spectrum. Where light waves tell us about the sizes of small particles, radio waves can tell us about the sizes of objects ranging in size from golf balls to houses.

<u>Science Standards</u>

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

10. Understands basic concepts about the structure and properties of matter.

Level I: Primary (Grades K-2)

- Knows that different objects are made up of many different types of materials (e.g., cloth, paper, wood, metal) and have many different observable properties (e.g., color, size, shape, weight).
- Knows that things can be done to materials to change some of their properties (e.g., heating, freezing, mixing, cutting, dissolving, bending), but not all materials respond the same way to what is done to them.

Level II: Upper Elementary (Grades 3-5)

- Knows that objects can be classified according to their properties (e.g., magnetism, conductivity, density, solubility).
- Knows that materials may be composed of parts that are too small to be seen without magnification.

15. Understands the nature of scientific inquiry.

Level I: Primary (Grades K-2)

- Knows that learning can come from careful observations and simple experiments.

Level II: Upper Elementary (Grades 3-5)

- Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world.
- Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer.
- Plans and conducts simple investigations (e.g., makes systematic observations, conducts simple experiments to answer questions).

Level III: Middle School/Jr. High (Grades 6-8)

- Establishes relationships based on evidence and logical argument (e.g., provides causes for effects).

Level IV: High School (Grades 9-12)

- Knows that a wide range of natural occurrences may be observed to discern patterns when conditions of an investigation cannot be controlled.

Scattering Student Sheet

Procedure

Your teacher will set up the experiment.

- The teacher will shine the laser through a glass of water. What do you see as the glass is rotated?
- The teacher will then add milk, flour, or some other substance. How does the laser beam change as it passes through the water mixture when the glass is rotated? How does the beam change as you look at it from the side?
- The teacher will experiment with different substances in the water. Observe how the beam changes as each different material is used.

Questions

- What are some examples of light scattering in everyday life?
- Which materials work well? Which don't?

Jet Propulsion Laboratory

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Seeing the Microscopic Among the Giants

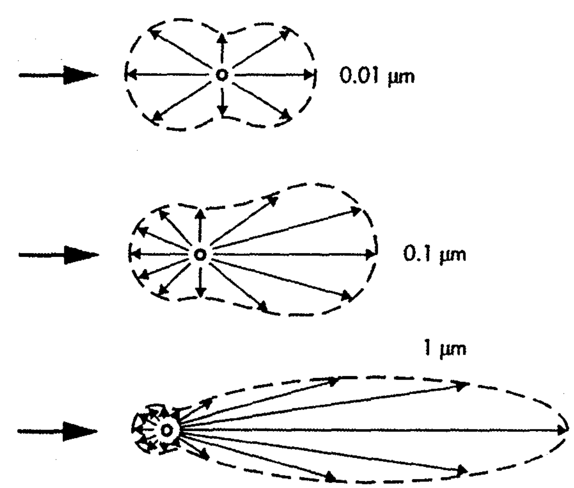
Ring Particle Scattering

Objective:

Demonstrate that passing radio and light waves through planetary rings and atmospheres permits studies of particle sizes and volume densities.

Process:

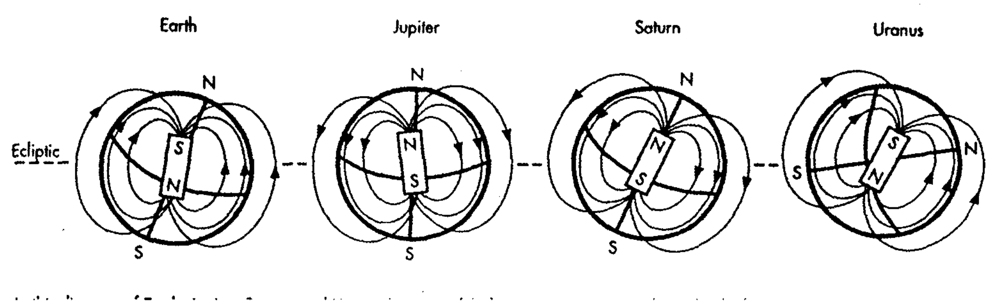
A laser pointer and a solution of highly diluted milk in Water demonstrate forward scattering.



Light scattering versus particle size

Cow Magnet Planets

Planetary Magnetic Fields



Objective:

Demonstrate how simple measurements allow determination of the orientation of a planetary magnetic field.

Process:

A magnet camouflaged in a ball mimics a planetary magnetic field. By making observations of a magnetic compass at no more than six locations surrounding the ball, the tilt and offset of the "planet's" magnetic field can be inferred relative to the rotational axis.