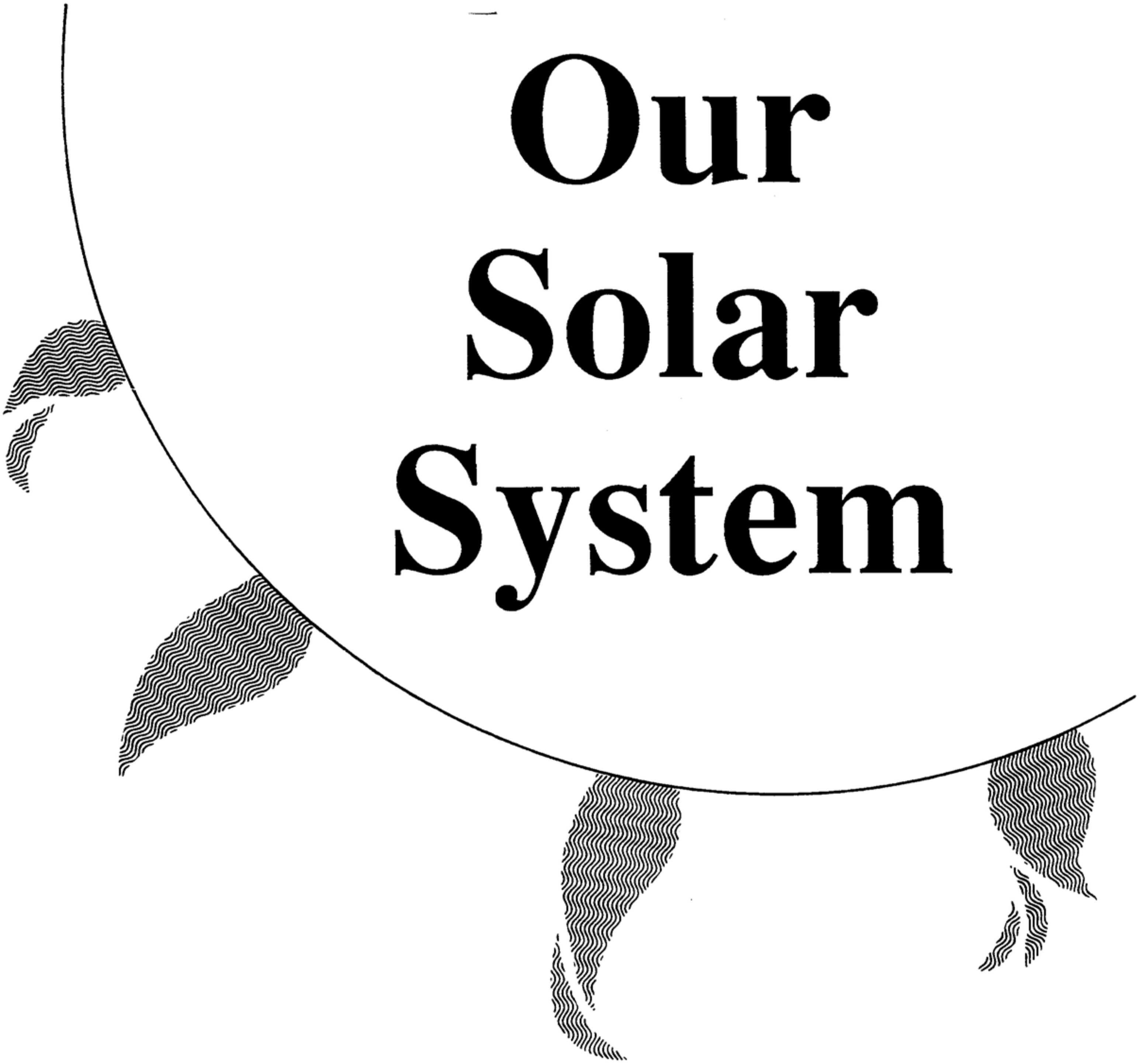
Our Solar System



Teacher's Guide and Activities

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Introduction

This *Teacher's Guide and Activities* booklet serves two purposes. First, it is a companion resource to both the **Our Solar System** video (K–3) and the written materials (K–3, 2–5). In this guide we try to clarify information and anticipate questions the teacher and/or the student might have. In many cases, we start out with a simple answer and then continue with a more detailed explanation.

Second, this booklet contains 12 classroom activities. These activities are appropriate for a variety of grade levels and seek to integrate mathematics, language arts, and social studies with the solar system material.

Our Solar System: The Booklets

When you discuss elliptical orbits with your students, the major points to make are that: 1) the orbits are not circular; 2) they are not egg-shaped or oval (as one often sees in children's books); and 3) ellipses are essentially flattened circles. If you tilt a circle you get a figure that **looks** like an ellipse; however, the orbits of the planets are **really** ellipses, not tilted circles.

Responses to K–3 Challenges

What do you think made the craters on Mercury?

The craters on Mercury, just as most craters on all the other bodies in the solar system, are due primarily to *impacts.* In the billions of years since the solar system formed, many asteroids, meteoroids (pieces of asteroids), and comets have collided with Mercury and the other planets. These chance collisions are very rare. The fact that the surfaces of Mercury, the moon, and many other satellites in the solar system show so many of these impact scars tells us that these surfaces are very old indeed.

What would happen on Earth if thick clouds made it very hot all the time?

Thick clouds of water vapor would keep Earth very warm. This would cause the land and sea surfaces to heat up over time. Hot temperatures would eventually cause the continents to get much *drier* as the moisture evaporated. Many fertile farmlands would become deserts. It would get harder and harder to grow enough food to feed Earth's population.

Hot temperatures over the oceans similarly would cause evaporation to increase. This would put *even more* moisture into the atmosphere. More moisture in the atmosphere means—that's right—even *thicker* clouds. Even thicker clouds means Earth would trap even more heat and get hotter still. The cycle would repeat itself, with more evaporation occurring, and the clouds thickening yet again. This cycle is sometimes called the *runaway greenhouse effect.* It is conceivable that with a runaway greenhouse Earth would eventually (over many centuries) come to look very much like the planet Venus.

Do you think there are plants and animals anywhere else in the solar system?

It is unlikely that there are either plants or animals elsewhere in the solar system at the present time. In order for life to develop and survive somewhere, the conditions there must be rather special. The place must not be too hot or cold. It would have an atmosphere thick enough to protect the life from the harmful ultraviolet rays of the sun and other stars, but not so thick that it blocked out the sunlight (the ultimate source of energy). A supply of the elements carbon, oxygen, hydrogen, and nitrogen would be necessary, as these elements are the *building blocks* of life. A plentiful source of *liquid* water also most likely would be required.

The only planet we know about that clearly has all these things at the same time is Earth. Mars' atmosphere is too thin—harmful rays reach the surface and water presently does not exist as a liquid on the surface. Venus is far too hot and too dry for life—any liquid water would rapidly boil off as steam. The other planets probably are even less hospitable than these two, our closest neighbors.

Scientists do not know whether Mars and Venus were *always* the same as they are today. Probably they were not. At one time in the far distant past, hundreds of millions of years ago, Mars almost certainly had liquid water. Something had to carve out the channels and canyons which we see, and water is the most likely fluid. The question then becomes, "If Mars had liquid water and a thicker atmosphere in the past, did these conditions exist long enough for life to establish itself?"

If you were planning a trip to Mars, what would you take on your trip?

The atmosphere of Mars is very thin, too thin to breathe and so thin that harmful ultraviolet rays from the sun reach the surface. (It is these rays which cause sunburn on Earth on clear days.) Even if the air were thick enough to breathe, it is mostly made of carbon dioxide. We would have to bring spacesuits to wear, so we could surround our bodies with oxygen and protect ourselves from the harmful rays. Since we do not think there is life on Mars, we would also have to bring our own food to eat. Mars probably has frozen water under its surface, which could be melted and used to drink. We would also need to bring some sort of equipment to generate power as well. Unlike Earth, Mars probably has neither coal nor oil (these are fossil fuels, made from the bodies of plants which lived millions of years ago). We would need to bring some means to generate energy—solar cells or nuclear generators. This energy would be needed to heat our spacesuits and to purify our air.

What do you think you would see if you could send a spacecraft through the clouds of Jupiter?

Unlike Earth, whose clouds are almost all water vapor (some are smog caused by air pollution), Jupiter has many different levels of clouds. Each layer of clouds is made of a different chemical. The topmost clouds are white and made of ammonia crystals. As our spacecraft descended deeper into the atmosphere, it would encounter cloud layers of other chemicals, such as ammonium hydrosulfide. Lower down, we think there is a very thick cloud deck of water ice crystals and water vapor. Tiny amounts of other chemicals, such as compounds of sulfur, are dissolved in these clouds. These chemicals are responsible for the colors of Jupiter's clouds: white, brown, red, and orange.

The *Galileo* spacecraft will send a probe into Jupiter's atmosphere when it arrives at the giant planet in 1995. It is hoped that the probe can sample the different chemicals in many of Jupiter's cloud decks on its way down, and send the information it gathers back to Earth. Eventually, the probe will sink so far down into Jupiter's dense atmosphere that it will be crushed. By then, it will have told us much more about the composition, temperature, and thickness of the clouds and atmosphere than we now know.

Why don't the chunks of ice in Saturn's rings melt?

Saturn is very far from the sun—ten times Earth's distance from the sun. As a result, Saturn receives only about 1/100 as much heat and light energy as Earth. Saturn is *very* cold—much colder than the coldest night at the South Pole of Earth. At this very low temperature, ice is a very hard substance—harder than most rocks on our planet. Therefore, the ice neither melts nor sublimes (turns from solid to gas).

Imagine that you have found a new planet in our solar system. Tell about your planet in words or draw a picture. Where is your planet in our solar system? Is it hot or cold? What does it look like?

There is plenty of room here for a student's imagination to come up with a planet. If the planet were closer to the sun than Earth, it would be warmer than Earth is. If it were farther away, it would be colder. An ideal planet would probably be somewhere between Earth and Mars, but bigger than Mars. Being bigger than Mars, it could retain a thicker atmosphere. The thicker atmosphere would allow it to have life as we know it: not too warm yet not too cold, with water and some oxygen in its atmosphere.

Other things to think about: does the planet have a moon(s), what is its gravity relative to Earth, how long is its day, etc.

Think about Jupiter, Saturn, Uranus, and Neptune. How are these four planets alike? How are they different?

These four planets are called **gas giant** planets. They are much larger than Earth, and they orbit much farther away from the sun than does Earth. They all have very deep atmospheres, made mostly of gases like hydrogen, helium, and methane, with very thick clouds. Each has many satellites and rings. Uranus and Neptune appear slightly bluish, while Jupiter and Saturn are more colorful, with clouds of red, orange, and brown. Jupiter and Neptune have huge storms called the Great Red Spot and the Great Dark Spot. The Great Red Spot has been observed by astronomers for over 300 years. Saturn and Uranus also have huge storms, but only rarely.

Pluto is the last known planet in our solar system. If you could go beyond Pluto, what do you think you would find?

Astronomers have searched for planets beyond Pluto for a long time—nearly a century now—but have not found any. If any such planets exist, they would be very faint. This means they are either fairly small or very far away from the sun, where it is very dark. Such planets would be similar to Pluto, that is, very cold and very icy. Some astronomers are still searching. One such object was found in September, 1992, but was found to be much smaller than the smallest planet.

Beyond the orbit of Pluto, we know there are many thousands of small, dark, icy bodies. They are called comets. Every now and then, a comet visits the warmer space closer to the sun, where Earth orbits. When a comet does this, it heats up and the icy material from which it is made sublimes (turns from a solid to a gas). We see this dusty, icy material as the coma and tail of the comet.

Responses to 2–5 Challenges

How would Earth be different if our sun were replaced by a much hotter star or a much cooler star?

If we replaced the sun with a star which was even a little cooler, the effect would be very drastic. Earth would cool down. Winters would be longer and colder, summers would be shorter and cooler.

In detail, much more would happen. More of the surface of Earth would be covered with snow during the longer winters. More of Earth's water would freeze out into the polar ice caps. This in itself doesn't seem too bad, but the ice and snow in the ice caps (and all over Earth) are *very* reflective—more of the light and heat energy from the cooler star would be bounced back into space instead of staying near Earth's surface to keep things warm. So Earth probably would cool even more. This means that more water would freeze out into the ice caps, to reflect still *more* energy back into space, which causes still further cooling. Earth would find itself in another Ice Age. With all the extra water being locked up in Earth's polar caps, sea level would drop—not very much, but even a hundred feet or so would have drastic effects on Earth. Much of the planet's seafood supply comes from the shallow waters near the coastlines of the continents. If these shallow places dried up, it would be difficult to support much of the life we have on Earth today. The cooler temperature would mean many of the best farmlands today would become unusable. So the food supply, both from land and sea, would decrease.

Most of mankind's large cities are near the coast. They would find themselves suddenly inland, and shipping of food and goods between cities would become much more difficult. Survival would become a very difficult thing to ensure.

On the other hand, if the sun were replaced by a star just a little bit warmer, the results could be just as bad. A hotter star would cause the land and sea surfaces to heat up over time. Summers would be hotter and longer, winters would be shorter and warmer.

Again, in detail much more would occur. Hot temperatures eventually would cause the continents to get much *drier* as their moisture evaporated. Many fertile farmlands would become deserts. It would get harder and harder to grow enough food to feed Earth's population.

Hot temperatures over the oceans similarly would cause evaporation to increase. This would put *even more* moisture into the atmosphere. More moisture in the atmosphere means—that's right—even *thicker* clouds. Even thicker clouds means Earth would trap even more heat and get hotter still. The cycle would repeat itself, with more evaporation occurring, and the clouds thickening yet again. This cycle is sometimes called the *runaway greenhouse effect.* The polar ice caps would melt, causing flooding of coastal cities, until this water, too, was evaporated. It is conceivable that with a runaway greenhouse Earth eventually (over many centuries) would come to look very much like the planet Venus.

Either way, Earth and its life would be in a lot of trouble. It is because neither one of two disasters has occurred that scientists are certain the sun has been shining with a very constant brightness for hundreds of millions of years.

What do you think made the craters on Mercury?

The craters on Mercury, just as most craters on all the other bodies in the solar system, are due primarily to *impacts.* In the billions of years since the solar system formed, many asteroids, meteoroids (pieces of asteroids), and comets have collided with Mercury and the other planets. These chance collisions are very rare. The fact that the surfaces of Mercury, the moon, and many other satellites in the solar system show so many of these impact scars tells us that these surfaces are very old indeed.

What can we learn from a spacecraft that lands on a planet? What can we learn from a spacecraft that orbits a planet?

Orbiting spacecraft and landers tell us very different things about a planet. For this reason, it is best to try to send some of each to a planet. Each can do its own job best, and together we would learn more about a planet than if only one type of spacecraft were used.

Having a spacecraft land on a planet is the best way to examine very small things on the planet. A lander can gather up samples of soil and rocks to analyze. There are ways to tell how old the soil and rocks on a planet are, and close examination of them tells a lot about what things happened to them in the past that made them what they are today. A lander is the best way to tell if there are earthquakes on a planet, and what is going on under the surface. It can measure how much heat there is coming up from under the ground, which tells us much about the inside of the planet. It is easier to search for life from a lander than from orbit, especially if the life doesn't build huge things like dams and cities. With a lander, you can pick and choose the things you want to study, and these things can be very small, while an orbiter forces you to look at many things at once. All sorts of different chemical tests can be done from a lander.

On the other hand, orbiting spacecraft (orbiters) are very good for observing *large* things, such as mountains, craters, plains, entire oceans, or deserts. They are a very good way to learn about the geology of a planet—what sorts of things happened on the planet's surface to make it look the way it does today. Also, by searching the whole planet for things like riverbeds and dry lakebeds, we can learn about the past history of the planet. For example, pictures of Mars taken from orbiting spacecraft lead us to believe that Mars had a lot of liquid water in the past. We do not see this water today. Orbiters are best for looking at very big things on the surface or keeping track of the weather on a planet. They make it easy to compare different spots on the planet which are very far apart.

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Scientists do not know whether Mars and Venus were *always* the same as they are today. Probably they were not. It is pretty certain that at one time in the far distant past, hundreds of millions of years ago, Mars almost certainly had liquid water. Something had to carve out the channels and canyons which we see, and water is the most likely liquid. The question then becomes, "If Mars had liquid water and a thicker atmosphere in the past, did these conditions exist long enough for life to establish itself?"

Find five books in the library with the word "moon" in the title. Choose one to read.

If you were planning a trip to Mars, what would you take on your trip?

The atmosphere of Mars is very thin, too thin to breathe and so thin that harmful ultraviolet rays from the sun reach the surface. (It is these rays which cause sunburn on Earth on clear days.) Even if the air were thick enough to breathe, it is mostly made of carbon dioxide. We would have to bring spacesuits to wear, so we could surround our bodies with oxygen and protect ourselves from the harmful rays. Since we do not think there is life on Mars, we also would have to bring our own food to eat. Mars probably has frozen water under its surface, which could be melted and used to drink. We would also need to bring some sort of equipment to generate power as well. Unlike Earth, Mars probably has neither coal nor oil (these are fossil fuels, made from the bodies of plants which lived millions of years ago). We would need to bring some means to generate energy—solar cells or nuclear generators. This energy would be needed to heat our spacesuits and to purify our air.

Plan a mission to Jupiter and its moons. Will your mission require an orbiter, a lander, or a flyby spacecraft? What will your spacecraft do when it reaches Jupiter and its moons?

The best mission to Jupiter would involve all three types of spacecraft, since each type is best-suited to do a particular job.

A flyby mission (like the Voyager spacecraft) is best for doing quick experiments. Jupiter is surrounded by very strong radiation belts, which are due to its intense magnetic field. These radiation belts very quickly can damage sensitive scientific instruments. To protect these instruments is very difficult and expensive. Flyby missions are the best way to plan more detailed missions involving orbiters and landers. Voyager measured the strength of Jupiter's radiation and magnetic field, and its camera took the first close-up pictures of Jupiter and its satellites. It gave us our first close-up look at the storm systems in Jupiter's massive atmosphere. By counting the number of craters on the surfaces of its satellites we now have a good idea how old these surface might be, and we learned something about the past history of these surfaces.

An orbiter mission is the best way to study how weather on Jupiter works. Again, a camera is the best way to do this. If pictures are taken over a long period of time, a movie of the cloud motions can be made. A spectrometer is an instrument for measuring the composition of things—and such an instrument could be used by an orbiter to tell us the composition of the different types of clouds, or the composition of different surfaces on the planet's moons. Since an orbiter stays with the planet for much longer than a flyby spacecraft, each of the satellites could be visited in turn, allowing much more detailed maps of the satellites to be made. The camera can be used to search for previously-undiscovered tiny moons or rings around the planet. Together with the spectrometer, the camera can be used to select the most interesting areas on the satellites where future landers could be sent most safely. Another instrument, called a photometer, measures the brightness of stars. By looking for brightness changes in stars right next to the limbs of the satellites, a photometer can be used to search for thin atmospheres around the satellites. Such an orbiter was sent on its way to Jupiter in 1989. It is called *Galileo* and will arrive at the giant planet in 1995.

Unlike Earth, whose clouds are almost all water vapor (some are smog, caused by air pollution), Jupiter has many different levels of clouds. Each layer of clouds is made of a different chemical. The topmost clouds are white and made of ammonia crystals. If our spacecraft descended deeper into the atmosphere, it would encounter other cloud layers of other chemicals, such as ammonium hydrosulfide. Lower down, we think there is a very thick cloud deck of water ice crystals and water vapor. Tiny amounts of other chemicals, such as compounds of sulfur, are dissolved in these clouds. These chemicals are responsible for the colors of Jupiter's clouds: white, brown, red, and orange.

The *Galileo* spacecraft will send a probe into Jupiter's clouds when it arrives at the giant planet in 1995. It is hoped that the probe can sample the different chemicals in many of these cloud decks on its way down, and send the information it gathers back to Earth. Eventually, the probe will sink so far down into Jupiter's dense atmosphere that it will be crushed. By then, it will have told us much more about the composition, temperature, and thickness of the clouds and atmosphere than we now know.

Landers are the best way to examine small regions on the solid surfaces of planets and moons. Jupiter probably has no solid surface, so it would be pointless to send a lander to it. However, the satellites all have solid surfaces, and a lander could do many useful experiments on them. No doubt a camera would show many interesting things from the surface of a satellite, but more revealing would be instruments to perform chemical analyses of the actual rocks and ice on the surfaces. By measuring the temperature at which the ice melts, we can tell what kind of ice it is. Is the ice made of water, or ammonia, or methane? An instrument called a seismometer looks for vibrations in the surface which tell of earthquakes and other activity inside the satellites. A geiger counter measures the radioactivity in rocks, and can tell scientists approximately when the rocks were made—in other words, how *old* they are. All of the experiments best done by a lander are ones which allow it to go out and pick up individual pieces of a planet or satellite. This is something which is impossible to do from an orbit many miles away.

How do you think Saturn's rings formed? Why don't the chunks of ice in Saturn's rings melt?

Saturn is very far from the sun—ten times Earth's distance from the sun. As a result, Saturn receives only about 1/100 as much heat and light energy as Earth. Saturn is *very* cold—much colder than the coldest night at the South Pole of Earth. At this very low temperature, ice is a very hard substance—harder than most rocks on our planet. Therefore, the ice neither melts nor sublimes (turns from solid to gas).

Scientists are not sure how the rings formed in the first place. Many believe that they were formed when a small, icy satellite was hit by a large object, such as a comet or an asteroid. The satellite was broken into millions of tiny pieces which eventually became the rings.

If you landed on one of the moons of Uranus, what do you think you would see in the sky?

The moons of Uranus all keep the same face toward Uranus, much like our moon keeps the same face towards Earth all the time. For this reason, if you landed on the side of one of Uranus' moons which faced *away* from Uranus, you would never see the planet! If you landed on the other side, however, Uranus would be seen hanging in the sky, and would never move from this position. (You would notice the same thing about Earth if you landed on the near side of the moon.)

Although Uranus would not budge from its position in the sky, it would seem to go through phases, much like the moon does in our sky. Also, because Uranus is so far from the sun, and the satellites do not have atmospheres to scatter the light, you would also be able to the stars in the sky all of the time.

Uranus would be, by far, the biggest object in the sky—10 to 200 times the size of the moon. The sun would be brighter than Uranus, but would appear only as a very bright point of light 1/400 as bright as we see the sun from Earth. The sun would still be much brighter than full moon on Earth, but would be too small to be seen as a disk. The brightest planet (other than Uranus itself) would be Saturn. However, at its closest, the distance from Uranus to Saturn is slightly greater than the distance from Earth to Saturn, so Saturn would appear a little fainter than we see it from Earth.

Jupiter, Saturn, Uranus, and Neptune are called the gas giants. How are these four planets alike? How are they different?

The *gas giant* planets all are much larger than Earth, and they orbit much farther away from the sun than does Earth. They all have very deep atmospheres, made mostly of gases like hydrogen, helium, and methane, with very thick clouds. Each has many satellites and rings. Uranus and Neptune appear slightly bluish, while Jupiter and Saturn are more colorful, with clouds of red, orange, and brown. Jupiter and Neptune have huge storms called the Great Red Spot and the Great Dark Spot. The Great Red Spot has been observed by astronomers for over 300 years. Saturn and Uranus also have huge storms, but only rarely.

Pluto is the last known planet in our solar system. If you could go beyond Pluto, what do you think you would find?

Astronomers have searched for planets beyond Pluto for a long time, nearly a century now, but have not found any. If any such planets exist, they would be very faint. This means they are either fairly small or very far away from the sun, where it is very dark. Such planets would be similar to Pluto, that is, very cold and very icy. Some astronomers are still searching. One such object was found in September, 1992, but was found to be much smaller than the smallest planet.

Beyond the orbit of Pluto, we know there are many thousands of small, dark, icy bodies. They are called comets. Every now and then, a comet visits the warmer space closer to the sun, where Earth orbits. When a comet does this, it heats up and the icy material from which it is made sublimes (turns from a solid to a gas). We see this dusty, icy material as the coma and tail of the comet.

What do you think you should do if you find an object you think is a meteorite? What would happen if an asteroid hit Earth?

If you find an object you think is a meteorite, you should be very careful to remember exactly *where* you found it. You should mark the spot somehow so that you can return to it if what you found turns out to be a meteorite, because there might be many more pieces of it lying around.

You should take the object you found to a geologist (or planetary astronomer, if there are any around). Geologists are scientists who are trained in the study of rocks, and some of them can identify a meteorite just by looking at it. Geologists know a lot about the different things that happen to meteorites in space and in passing through Earth's atmosphere. However, even a geologist can be fooled by what he or she sees. They can perform chemical tests on the object to see whether elements which are common in meteorites, but rare in Earth rocks, are present—elements like osmium and iridium, for example. Earth has osmium and iridium, too, but most of these metals have sunk into Earth's core, thousands of miles beneath the surface. Geologists work at places such as universities and museums of natural history.

What would happen if an asteroid hit Earth would depend on how large the asteroid was. Where on Earth it hits is important, too. Since most of Earth is covered by water, chances are that the hit would occur in the water. A small asteroid probably would make a very large splash, and then sink to the bottom, probably never to be found. The same size asteroid, if it hit land, would probably dig out a *crater*. Such impact craters are usually about ten times as wide as the object which made them. For example, Meteor Crater in Arizona is about a half mile across. It was formed when Earth was hit by an object that was bigger than a house, made mostly of nickel and iron. It isn't likely that such an impact did much to affect Earth, but it surely made a mess of its immediate surroundings, and to a distance of possibly hundreds of miles.

What would happen if a much larger asteroid smashed into Earth? The effect would be much more harmful. A much larger crater would be dug out by the object, and the rock and dirt that used to fill this crater, along with pieces of the asteroid, would be flung high into Earth's stratosphere. The larger pieces would fall almost immediately, but the very fine, dust-sized particles would be caught up by the high-altitude winds. Eventually, these winds would carry the fine particles all the way around the globe.

If a large asteroid hit on water, it would punch right through the surface, turning the water into steam and forming a crater on what used to be the sea floor. Fine particles of sea floor would be lifted high into the atmosphere, as with the impact into the land.

The fine, dust-sized particles in the atmosphere would block out the sunlight before it could get to Earth's surface. For months or years, our days would be very dark. Plants would not get enough sunlight to live. If Earth went for months or years without sunlight getting to the surface, it would get rather cold. Many plants would die, and then the animals who normally eat these plants would die. Then the animals who ate the other animals would soon die. Many different types of life could disappear entirely! Most scientists are now convinced this is precisely what killed off the dinosaurs 65 million years ago.

Go to the library and look up articles and books on the history of comets. What did people think about comets hundreds of years ago?

Design a Planet.

This exercise is intentionally open-ended in order to get the student to think. Working as a group with the teacher as a discussion leader probably is the most useful approach. The example below is just one of many possible "answers."

Let's design a planet between Mars and Jupiter, one that is habitable by life somewhat like that on Earth. Since the planet is much farther from the Sun than Earth is, it is likely to be much cooler than Earth unless we "design in" some way to compensate. The planet ideally would be somewhat larger than Earth, but made of similar material (rock and metal), so that it would have a stronger gravitational field. This stronger field would be useful to help it retain a thicker atmospheric blanket. A thicker atmosphere would help the planet retain what little heat it receives from the Sun. It would also shield the surface from meteoroids and small asteroids which are likely to be present so close to the asteroid belt. Any plants on the planet would have to be much more efficient at using sunlight than Earth-type plants. The planet would have to rotate about once in 20 or 30 hours so one side doesn't get too cold (or else the life forms would be limited to living on the day side). Still, the temperature of the planet probably is cooler than that of Earth, and probably would have large polar ice caps. The animals on our make-believe planet would need thick coats of fur to help them keep warm. Although they could survive on the surface, they would probably spend most of their time in caves.

Higher lifeforms (indigenous or colonists from Earth) would also need protection from the elements. This might include warm clothes, protected habitats (underground, domed, etc.), and controlled climates for raising food supplies. Non-humanoid lifeforms may have adapted to the cooler temperature and increased radiation, but would still need protection from meteoroids.

Our Solar System: The Video

The view of the sun and the planets in their orbits is only a computer-generated sketch, drawn very simply to show the orbits of the planets. The planets are not drawn to scale, nor are the distances between the planets to scale. Even though the orbit of Pluto crosses the orbit of Neptune we have not shown this for simplification. Voyager has taken pictures of our solar system after it left the solar system, but those pictures were individual images of very faint, small, and distant objects, not just one picture of the whole solar system. Also, some children may need to be reminded that the orbits are *not* lines in space that one can actually see. They are drawn in to help show the paths of the planets around the sun.

The flight through the solar system past the planets is again computer generated. Some of the images were generated from photographs of the planets, but most were sketched. In reality, the planets are rarely aligned as we have them in the video. Again, this was done for simplicity, rather than try to have the spacecraft flying back and forth from one planet to the next at different positions in their orbits (as they are in the overall view of the solar system). The planets are not shown to scale. If we did that we would have a huge Jupiter and barely be able to see Mercury and Pluto.

Wherever possible, we have tried to get full disk images of the planets. This could not be done for either Mercury or Pluto. Mariner only photographed about half of Mercury; the images we show have lines because the images are mosaics of many smaller images of the planet. The image of Pluto was taken by the Hubble Space Telescope. It is "fuzzy" because of the well-known problem with the optics of Space Telescope. However, the "bump" on the image to the lower left is actually Pluto's satellite Charon!

The image of the surface of Venus and the full-disk image of Venus are computer-generated pictures made from Magellan radar images. The color is derived from pictures of the surface taken by Soviet landers. The color is primarily due to the filtering of light through Venus' thick atmosphere. The rocks are actually fairly gray in color.

ACTIVITY A

Planetary Poetry

Integration: Language Arts, Fine Arts

Process Skills: Communicating, describing

Objectives:

Combine science facts with language arts (poetry) and fine arts (illustration).

Materials:

Pen or pencil, lined paper
Optional: oak tag or construction paper for cover

Procedures:

Choose a planet or other solar system object; review with class the facts known about this object.

Describe one of the poetry styles; brainstorm and compose a poem as a group.

Ask students to choose a solar system object, list facts they know about it, and compose their own poem.

Younger students should be supplied with a "shaped" booklet, i.e., sturdy front and back cover to be illustrated, with lined paper inside for their poem; shapes could be planets (round), spacecraft, comets, volcanoes, etc.

Alternative: a construction paper or oak tag backing with lined paper glued on would allow poems to be displayed on a bulletin board.

HAIKU: contains highly evocative allusions and comparisons, expresses love of nature

Construction: 5 syllables, 7 syllables, 5 syllables

Venus, our sister
Shrouded, mysterious orb
Shining silver clouds

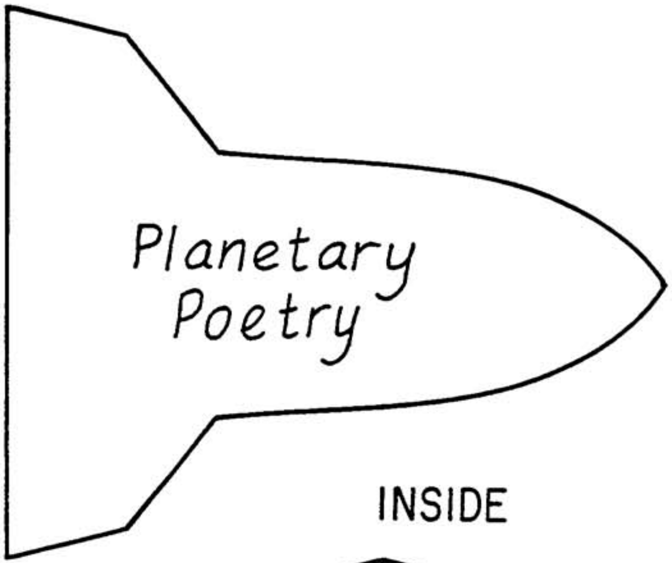
Mars, red warrior
Deep canyons, pink dust swirling
Lifeless, frozen world

CINQUAIN: a stanza of five lines; may be constructed as follows:

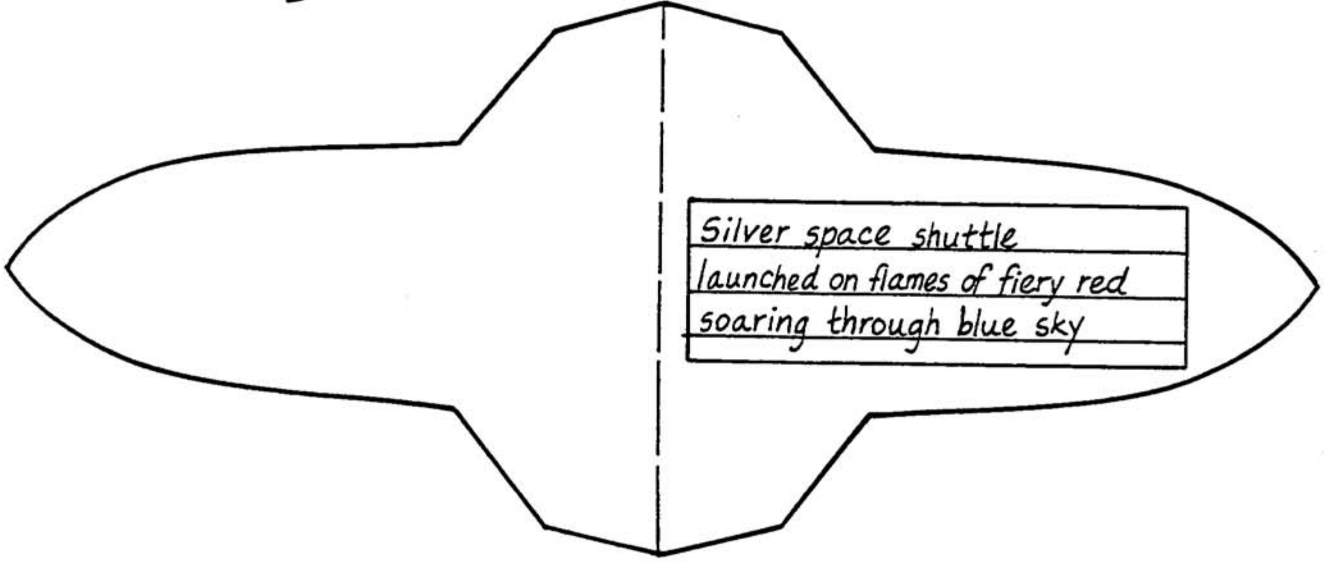
one word, noun
two words, describes line 1
three words, action of line 1
four words, your feelings about subject
five words, tying together [or 1 word, same or similar to line 1]

Planet
Icy cold
Orbiting the sun
Mysterious, remote, unknown world
Pluto

FRONT COVER



INSIDE



ACTIVITY B

Ellipses

Integration: Mathematics

Process Skills: Using spatial relationships, observing, analyzing, inferring

Objectives:

Students will learn that the orbits of the planets are elliptical in shape rather than circular, oval, or egg-shaped.

When doing these activities, the point to make is that a tilted circle **looks** like an ellipse, but that the orbits (even though they are tilted with respect to one another) are actual ellipses and not circles.

Materials:

Illustrations on following page, small circular plate, overhead or slide projector, pencil, paper, tape, protractor

Procedures:

The illustration on the next page is divided into two parts; the top part is for primary and intermediate grades while the lower part is for intermediate grades only.

Show students the top figure and demonstrate in the class with the plate that when you tilt a circular object you get a figure that looks like an ellipse.

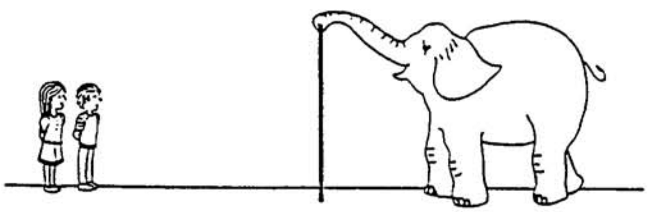
Place the plate vertically in front of the light source (or horizontally on the overhead projector) and project a shadow of the plate on the wall or a screen.

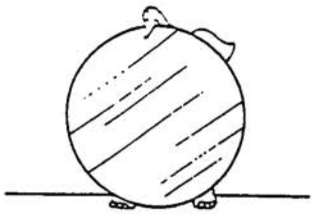
Have the students predict what will be seen as the plate is tilted.

Place a piece of paper on the wall and have the students outline the shadow of the plate.

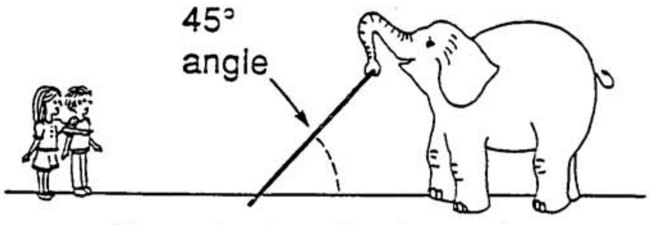
For intermediate students, have them measure the tilt of the plate and compare the shape of the ellipse produced on the wall with the bottom illustration on the following page.

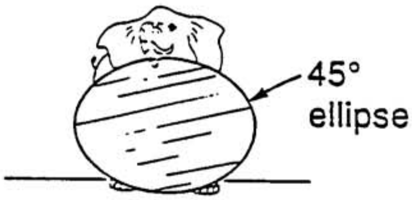
Answers to Math Questions: A 0° ellipse is a line. There are many lines on the page, but in particular there are the two side views of the elephant holding the circles that appear to be 0° ellipses.





If you look at the front of a circle
that is standing straight up,
you will see . . . . a circle !

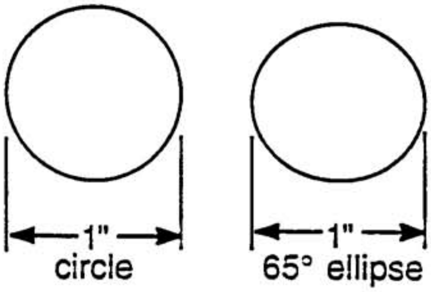




If you look at the front of
a tilted circle, you will see . . . . an ellipse !

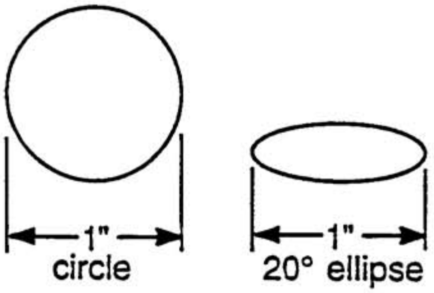
* * *

The shapes of the orbits of the planets are not circles. The shapes are ellipses. Ellipses have many different sizes. They can be almost the same as a circle,



only slightly tilted
or flattened,

or they can look very different -



tilted or flattened a lot !

The smaller the degree number that describes the ellipse, such as 65° and 20° shown above, the shorter (more tilted or flattened) the ellipse will be.

Math Questions

What do you think a 0° ellipse would look like?
Is there a picture of one on this page?

ACTIVITY C

Planetary Mythology

Integration: Language Arts, Fine Arts, Social Studies, Literature

Process Skills: Interpreting, recognizing relationships

Objectives:

Students will learn how the planets and their moons were named. Students will become familiar with the myth form and with myths from various cultures.

Materials:

A variety of books on myths and legends, including Roman and Greek myths pertaining to the planets, Native American myths relating to the sky, and sky lore from other cultures.

Pencils, lined paper, art supplies

Procedures:

Brainstorm with the class about how planets and their moons were named. Choose one of the planets and read the Roman or Greek myth describing the appropriate character. Ask the students why the planet was named after the particular character (e.g., Mars was a fierce, fiery god, which is appropriate to the red planet, Mars; the moons of Neptune are named after water deities; the planet Venus is mysteriously shrouded in clouds, making it a beautiful silver object appropriate to the goddess, etc.).

Discuss the myth form of literature. Read a Native American myth describing some aspect of sky lore. Provide examples of myths and legends from other cultures.

Optional: Ask the students (individually or in small groups) to choose a planet they would like to re-name. Have the students list some of the characteristics of the chosen planet (e.g., Pluto is icy, cold, faint, far away, unknown). Ask the students to write their own myth about their chosen planet, devising a character to represent the planet. Try to match the characteristics of the mythical character to the chosen planet. (Example: a dark, mysterious character such as Darth Vader from *Star Wars* would be an appropriate modernization for Pluto!)

Optional: Ask the students to illustrate their myths.

Names of Surface Features

Examples from Jupiter's Moons:

Io	Gods and heroes associated with fire, sun, thunder, or volcanoes; also, people and places associated with the Io myth
Europa	European (Celtic) gods and heroes, places in ancient Egypt, people and places associated with the Europa myth
Ganymede	Gods, heroes, and places from ancient Egypt and the fertile crescent
Callisto	People and places from northern myths

Examples from Saturn's Moons:

Enceladus	People and places from Sir Richard Burton's version of the *Arabian Nights.*
Rhea	People and places from African, Asiatic, and South American creation myths

Examples from Uranus' Moons:

Ariel	Bright (good) spirits from worldwide mythologies
Umbriel	Dark (evil) spirits from worldwide mythologies

Example from Neptune's Moons:

Triton	Aquatic gods and places

*Derived from *Satellites of the Outer Planets*, David A. Rothery, 1992.

ACTIVITY D

Humans in the Martian Environment

Integration: Social Studies

Process Skills: Observing, inferring, analyzing, making judgments, describing

Objectives:

Reinforcing factual material about Mars; critical thinking/problem solving; optional: designing a structure and/or vehicle to fit predetermined criteria

Materials:

Audiovisual materials about Mars; also, pictures of astronauts and vehicles on the moon

Audiovisual materials about Earth deserts and the Arctic, featuring people, vehicles, and structures

Optional: Paper, art supplies, building materials as needed for design projects

Procedures:

Discuss the martian surface, atmosphere, and environment. Use slides, videos, and posters to reinforce what Mars is like. Brainstorm with the class what problems humans exploring Mars might encounter (e.g., lack of water, oxygen, temperature extremes, dust, terrain).

Using slides, videos, and posters, show the students how lunar explorers coped with lack of gravity, lack of oxygen, and transportation. Brainstorm with the students how martian explorers might cope with environmental hazards on Mars. Compare the length of the journey to the moon with the length of the journey to Mars.

Again using audiovisual materials, discuss with the students how people on Earth who live in deserts and very cold regions have adapted to sand and dust storms, temperature extremes, lack of water, etc.

Have students work in small groups to (a) design a structure that would allow humans to live and work on Mars, and (b) design a vehicle that the workers could use on the dusty, rocky surface of Mars.

Optional: The students can present their designs as drawings or can build 3-D models according to skill level and materials available.

ACTIVITY E

Global Astronomy

Integration: Fine Arts, Social Studies

Process Skills: Classifying, recording

Objectives:

Students will gather and chart information by using library resources. Optional: Students will use a map or globe to find the appropriate locations.

Materials:

Almanac, encyclopedia, dictionary, or wall chart showing flags of the world (Option: use state flags)

Pencils and blank charts to fill in (see following pages for examples)

Optional: map or globe

Procedures:

Ask the students to name some of the solar system objects they have studied. Ask if they have ever seen pictures of the sun, stars, or moon on a country's flag (Optional: the sun or stars on a state's flag). The stars on the U.S. flag should be an easy example.

Direct the students to the appropriate resource materials (e.g., almanac, encyclopedia, dictionary, wall chart) and ask them to list the countries (or states) whose flags show astronomical objects. The chart on the following page may be used as is, or may be simplified or revised to the appropriate skill level.

Ask the students (individually or in small groups) to locate the countries (or states) they have listed on a globe or map.

Optional: Brainstorm with the students which symbols might represent our planet or solar system. Ask students to design a flag to represent Earth.

Optional: Ask the students to select a country (or state) from their list to research for a report.

ASTRONOMY AROUND THE WORLD

List 7 countries with stars on their flags.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________

List 7 countries with moons on their flags.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________

Challenge: Find a country with the sun on its flag.

____

STARS IN THE STATES

List all of the states with stars on their flags.

Challenge: Find a state flag which shows the sun.

ACTIVITY F

Scale Model Solar System

Integration: Mathematics

Process Skills: Modeling, measuring, using spatial relationships

Objectives:

Using the size chart given, students will calculate two new size scales for the planets, keeping them in proportion to each other.

Materials:

Size chart on page 33 of *Our Solar System* (grades 2–5 version)

Reproducible chart (see page 24)

Optional: Pencils and paper for calculations; rulers

Optional: Colored paper, scissors, markers or crayons for bulletin board display

Procedures:

Have the students look at the size chart. Explain that the planets and moons are drawn *in proportion.* For example, the real Uranus (about 32,000 miles across) is about 4 times larger than the real Earth (about 8,000 miles across).

The artist had to choose a size scale which would allow her to fit the solar system chart on one booklet page. Uranus still had to be about 4 times bigger than Earth. Allow the students to measure Uranus and Earth on the size chart. Uranus is a 1-inch circle and Earth is a 1/4-inch circle. The students should conclude that the artist represented Uranus as being about 4 times larger than Earth.

Optional: Brainstorm with the students why the artist did not choose a larger or smaller size for Uranus. Point out that Jupiter must be about 3 times larger than Uranus. Have the students measure Pluto or Mercury to see why a smaller scale would not work.

Plan a bulletin board display with the students. The planets should be larger than those on the size chart, but they must be small enough to fit on a classroom bulletin board.

Introduce the reproducible chart. This chart gives the *approximate* size of each planet on the booklet size chart. Ask the students to add or multiply the first column of sizes to find out what the planets would look like if they were scaled twice as big or four times as big as those on the size chart.

Have the students choose the column which would make the most attractive bulletin board display. Optional: create a bulletin board display with the planets in proportion to each other *by size*. Students may add special features, rings and moons.

NOTE: The sizes listed on the reproducible chart are *approximations*, as the actual sizes (Mercury = 7/64″, Venus = 7/32″, Mars = 5/32″) may be difficult for the students to manipulate. Also, the sun was not included on the size chart because it would need to be about 30 times larger than Uranus. The class may want to take this into account in planning their bulletin board, brainstorming ways to represent a small portion of the sun to scale.

Planet	booklet size	twice as big	four times as big
Mercury	1/8 inch	______	______
Venus	1/4 inch	______	______
Earth	1/4 inch	______	______
Mars	3/16 inch	______	______
Jupiter	3 inches	______	______
Saturn	2-1/2 inches	______	______
Uranus	1 inch	______	______
Neptune	1 inch	______	______
Pluto	1/16 inch	______	______

ACTIVITY G

Graphing the Solar System

Option A

Integration: Mathematics

Process Skills: Organizing graphs, interpreting data, recording, analyzing, making judgments, patterns

Objectives:

Students will gather information from the booklet and record their data on the graph provided.

Students will look for patterns in the data.

Materials:

A copy of the blank graph provided on page 27 of this guide. Students will need a copy of *Our Solar System* (grades K–3 version) for the information necessary to fill in the graph.

Lead pencils; red pencils, markers, or crayons

Procedures:

Introduce the students to the blank graph. Note the names of the planets across the bottom, the number of known satellites running vertically along the left side, and the space along the top of the graph for marking the existence of rings.

Brainstorm with the students ways in which to fill in the necessary information. Some students may suggest that they already know Earth has one moon and no rings. Researching the unknown information from the booklet will be the chosen procedure.

Allow the students to record the data on their graphs. Ask the students to look for patterns, e.g., planets beyond the asteroid belt have rings and the most moons, rocky planets are usually closer to the sun, Pluto does not fit the general pattern. If there is a size comparison chart in the classroom, children may note that the smaller planets have no rings and few, if any, moons.

Share other examples of graphs and charts with the class. Discuss why scientists use graphs and charts to display data. Discuss how much information can be fit on one page using a chart or graph, and how easy it is to find information and see patterns by using a chart or graph.

Working individually or in small groups, allow the students to choose a topic, gather data, and show the results on a chart or graph. For example, the class could chart the number of letters in each student's name. The results might show that 10 out of 20 students have names containing 6 letters, while only 1 student has a name containing 10 letters. If the school provides a student directory, the class could chart the number of students per grade, or the number of boys vs. girls by class, grade, or in the entire school. Over a longer period, students could chart the number of sunny days in a month, or the number of students who buy lunch vs. bring lunch for a month.

Are there rings? (*If a planet has rings, put a red X above its column*)

number of known moons	Mercury	V	E	M	J	S	U	N	Pluto
25									
24									
23									
22									
21									
20									
19									
18									
17									
16									
15									
14									
13									
12									
11									
10									
9									
8									
7									
6									
5									
4									
3									
2									
1									

asteroid belt

ACTIVITY G

Graphing the Solar System

Option B

Integration: Mathematics

Process Skills: Organizing graphs, interpreting data, recording, analyzing, making judgments, patterns

Objectives:

Students will gather information from the booklet and record their data on the chart provided.

Students will look for patterns in the data, answer questions based on the chart, and draw conclusions.

Materials:

A copy of the blank graph provided on page 30 of this guide. Students will need a copy of *Our Solar System* (grades 2–5 version) for the information necessary to fill in the graph.

Pencils

Procedures:

Share examples of graphs and charts with the class. Discuss why scientists use graphs and charts to display data. Discuss how much information can be fit on one page using a chart or graph, and how easy it is to find information and see patterns by using a chart or graph.

Introduce the students to the blank graph. Note that two planets call for both high and low temperature information. Note the location of the Asteroid Belt.

Brainstorm with the students ways in which to fill in the necessary information. Some students may suggest that they already know Earth's atmosphere or size. Researching the unknown information from the booklet will be the chosen procedure.

Discuss with the students why organizing facts (data) is an important part of scientific research. Allow the students to record the data on their graphs.

Ask the students to use the recorded and organized data to answer/discuss the following questions 1–4.

Working individually or in small groups, allow the students to choose a topic, gather data, and show the results on a chart or graph. For example, the class could chart the number of letters in each student's name. The results might show that 10 out of 20 students have names containing 6 letters, while only 1 student has a name containing 10 letters. If the school provides a student directory, the class could chart the number of students per grade, or the number of boys vs. girls by class, grade, or in the entire school. Over a longer period, students could chart the number of sunny days in a month, or the number of students who buy lunch vs. bring lunch for a month.

Planet	Temperature	Atmosphere	Composition: hard surface or core	Size
Mercury	high low			
Venus				
Earth	high low			
Mars	high low			
ASTEROID BELT				
Jupiter				
Saturn				
Uranus				
Neptune				
Pluto				

ACTIVITY G

Option B Questions

1. Look at the temperatures of the planets, in order from the sun. You might expect that the closest planet to the sun would be the hottest, the next planet a bit cooler, the next planet a little colder, and so on, with Pluto measuring the coldest temperature. Find the planets that do not follow this pattern. Scientists often look for patterns. When data do not follow the expected pattern, this is called an anomaly. Part of a scientist's job is to try to explain facts that do not seem to fit. Find two ways in which Pluto does not fit the patterns on the chart.

2. Look at the temperature, atmosphere, and composition columns for Earth. Humans could not exist on a planet with temperature, atmosphere, and composition much different from those on Earth. Study the data for the other planets. Which planet has temperature, atmosphere, and composition closest to that of Earth? What would humans need in order to explore this planet? Think about problems such as breathing, keeping warm (or cool), food, and water.

3. Look at the column that tells about each planet's atmosphere. Which planets have similar atmospheres? What else about these planets is similar? Why would these planets be hard for humans to explore? Think about what you have learned about the moons in the solar system. Could humans explore the moons?

4. Find the planets that are closer to the sun than the Asteroid Belt. Look at the facts you have recorded about these planets. Try to find patterns that tell how these planets are similar. Do the same for the planets that are beyond the Asteroid Belt. Try to find patterns in the facts you have recorded. Does Pluto fit the pattern for planets closer to the sun, or farther from the sun? [Hint: Consider temperature, composition, atmosphere, and size before you decide.]

ACTIVITY H
Solar System Reports
Option A

Integration: Language Arts, Fine Arts

Process Skills:

Objectives:

Students will learn how to spell selected words used in *Our Solar System* (K–3 version). They will write a short report on a chosen word/term from *Our Solar System* and will illustrate the report.

Materials:

Spelling words from *Our Solar System*
Lined paper, large sheets of manila drawing paper
Pencils, crayons
Our Solar System

Procedures:

Choose spelling words from *Our Solar System.*

Students choose one word/term for report.

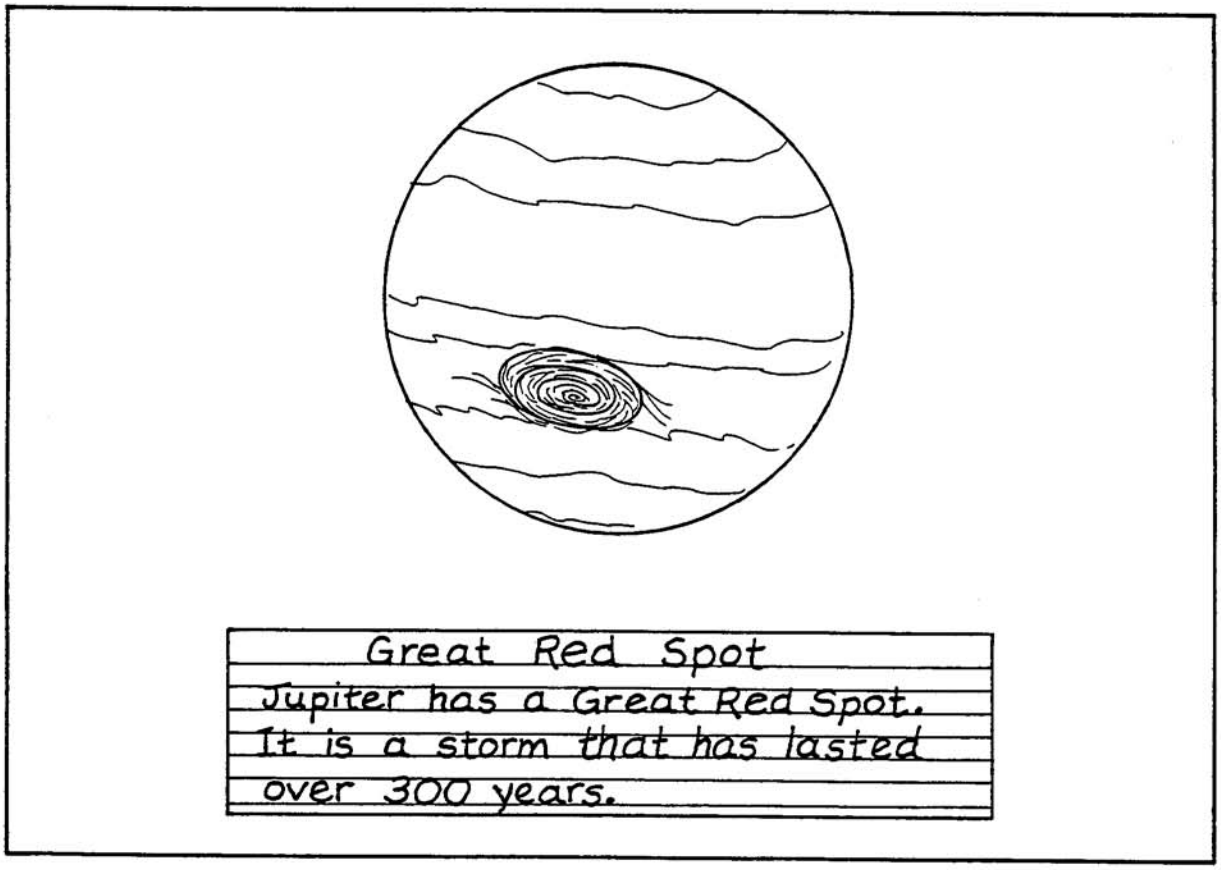
Students write two or three sentences about the chosen word/term on the lined paper.

Students illustrate their report on the upper 1/2 of the drawing paper (see illustration below).

Students glue the report below the illustration.

Suggested Words: cliff, cloud, crater, day, Great Dark Spot, Great Red Spot, ice, moon, mountain, night, orbit, rings, sky, solar system, spacecraft, star, storm, sun, telescope, valley, volcano, water, and the names of the nine planets.

Sample Report:



Great Red Spot

Jupiter has a Great Red Spot.
It is a storm that has lasted
over 300 years.

ACTIVITY H
Solar System Reports
Option B

Integration: Language Arts, Fine Arts

Process Skills:

Objectives:

Students will learn how to spell selected words used in *Our Solar System* (grades 2–5 version). They will prepare a research report on a solar system topic, and will illustrate the report.

Materials:

Spelling words from *Our Solar System*
Resource materials
Paper, pencils
Art materials
Our Solar System booklet

Procedures:

Choose spelling words from *Our Solar System*.

Students choose topic to research.

Students keep research portfolio.

Students write report based on research.

Students illustrate report.

Suggested Words: ammonia, asteroid, astronaut, atmosphere, carbon dioxide, coma, comet, composition, crater, ellipse, erupt, Galilean, Ganymede, greenhouse, helium, hydrogen, Io, lava, liquid, lunar, Magellan, meteor, meteorite, meteoroid, methane, nitrogen, nucleus, orbit, oxygen, planet, pressure, radar, reflect, solar system, spacecraft, sulfur, sulfuric acid, surface, telescope, temperature, Titan, Triton, valley, volcano, and the names of the nine planets.

Suggested Topics: Apollo program, asteroids, astronauts, Comet Halley, comets, greenhouse effect, light pollution, lunar landings, Kitt Peak National Observatory, Magellan, Meteorite Crater, meteorites, Pioneer, solar energy, space shuttle, space station, sun spots, Ulysses, Voyager, any planet or moon.

EXPERIMENT I

Moon Journal

Integration: Language Arts

Process Skills: Observing, recording data, predicting, communicating

Objectives:

Students will observe the phases of the moon, record the data in a moon journal and on a large piece of butcher paper, and make predictions about the phases of the moon.

Materials:

Newspaper, journals, pencils, butcher paper

Procedures:

Begin the moon journals at about the third quarter of the moon. Check the newspaper to find out when this will occur. At third quarter the moon will be visible in the west between morning and noon.

DAY ONE

1. Have the students look for the moon in the sky today. When they find it, have them write the time and date in their moon journals. Ask them to draw what the moon looks like, and to draw where the sun is compared to the moon. **WARNING:** Be careful not to look directly at the sun! Ask the students to count with a fist (held at arm's length) how many fists it is from the moon to the sun, and to record this number on their drawings.
2. Draw the results on a large piece of butcher paper taped to a wall in the classroom. (Use the chalkboard if you can keep it free for a week or more.) Ask the class to measure how many "fists" it is from the sun to the moon.
3. Ask the class to predict what the moon will look like and where it will be tomorrow at the same time.

DAY TWO

1. Observe the moon again. Repeat the observations of yesterday. Record the data and draw the moon and the sun in the moon journals. Draw the results on the butcher paper in the classroom.
2. Compare the predictions from yesterday with today's results. How good were the predictions? Ask the class to make the same predictions for tomorrow.

DAY THREE

1. Repeat the observations and the recording of the data. Is the moon getting closer to the sun? Will it pass above, below, in front of, or behind the sun? When? When will you next be able to see the moon? What will it look like then?
2. Continue the observations for a month and check the class's predictions. Keep a record in the moon journal and on the butcher paper in class for a month. Label the phases of the moon.

EXPERIMENT J

Daytime Astronomy—Shadow Observations

Integration:

Process Skills: Observing, recording data, predicting

Objectives:

The students will observe their own shadows, record their observations, and make predictions.

Materials:

1. Meter sticks (one for every two students)
2. Chalk (one piece for every two students)
3. Pencils and note cards

Procedures:

1. Introduction: Ask the students the following questions: Who has seen their shadow? What did it look like? Was it as long as you are tall? In what direction did it go? What makes your shadow?

2. Tell the students that they are going to observe their shadows to find out some facts about shadows. Take the class outside to a sidewalk or basketball court where there are no obstructions to the sunlight for several hours. Work in teams of two.

    a. Have one student (#1) from each pair stand still while their partner (#2) traces around #1's feet with chalk.

    b. Have #1 stand tall while #2 marks the top of the head on #1's shadow. Have #2 put his/her initials by the mark.

    c. Measure the length of the shadow with the meter stick. Record the measurement on the note card.

    d. Measure the actual height of student #1 from each pair. Record this measurement on the note card.

    e. How does the length of the shadow compare to the actual height of the student?

    f. Ask the pairs to predict where the top of #1's shadow will be in one hour. Make a mark there on the ground. Label with the marker's initials.

3. Check the shadows after about one hour. Be sure #1 stands in the space marked for his/her feet earlier.
    a. Which way did the shadow move, east or west? (east)
    b. Which way does the sun appear to move? (west)
    c. Which way is the earth turning? (east)
    d. Is the shadow longer or shorter now?
    e. Is the sun higher or lower now?
    f. When will the sun be highest? Ask the students if they think the sun will be the same height (altitude) next week at the same time of the day.

Note: This experiment has been included even though there is no discussion of day/night and rotation in *Our Solar System.*

EXPERIMENT K

Solar Cookers

Integration: Mathematics

Process Skills: Measuring, graphing, recording data, estimating, predicting

Objectives:

Students will construct a solar cooker to show how energy from the sun can be transferred to cook marshmallows and hot dogs. They will predict cooking times based on Day One experiment.

Materials:

1. White trays, black trays (about 8″ × 10″)
2. Clear plastic lids (or plastic wrap)
3. 1 cup of water per tray
4. Salt or oatmeal boxes
5. Shoeboxes
6. Dowels or skewers
7. Black paint
8. Paint brushes
9. Aluminum foil, plastic wrap
10. Tape
11. Graph paper, pencils or markers (2 colors)
12. Hot dogs and marshmallows

Procedures:

DAY ONE

1. Put 1 cup of water in each tray. Place trays in a sunny location.

2. Measure the temperatures of white trays vs. black trays; measure again after 15, 30, and 60 minutes.

3. Measure the temperatures of trays with lids vs. trays without lids; measure again after 15, 30, and 60 minutes.

4. Graph the results; discuss which tray heated the water faster and why.

DAY TWO

1. Brainstorm with students to list ways they would construct their cookers. They should deduce the best cooker would be in a black shoe box covered with plastic wrap.

2. Students test their theory by constructing cookers. Work in small groups, with each student having a cooker of their own.

3. Closure: Ask students to explain what they expect will happen and why.

DAY THREE

1. Students put cookers outside; 1/2 hot dogs, 1/2 marshmallows.
2. While food is cooking, students predict cooking times.
3. Brainstorm with students for both marshmallows and hot dogs, and why there might be a difference in times.
4. Have each student choose one of the listed predictions for each food and explain their choices.
5. Tally class predictions; work in small groups to graph the results.
6. One or two students should be guarding the cookers (watch out for ants!), and should signal when it looks like the food is ready.

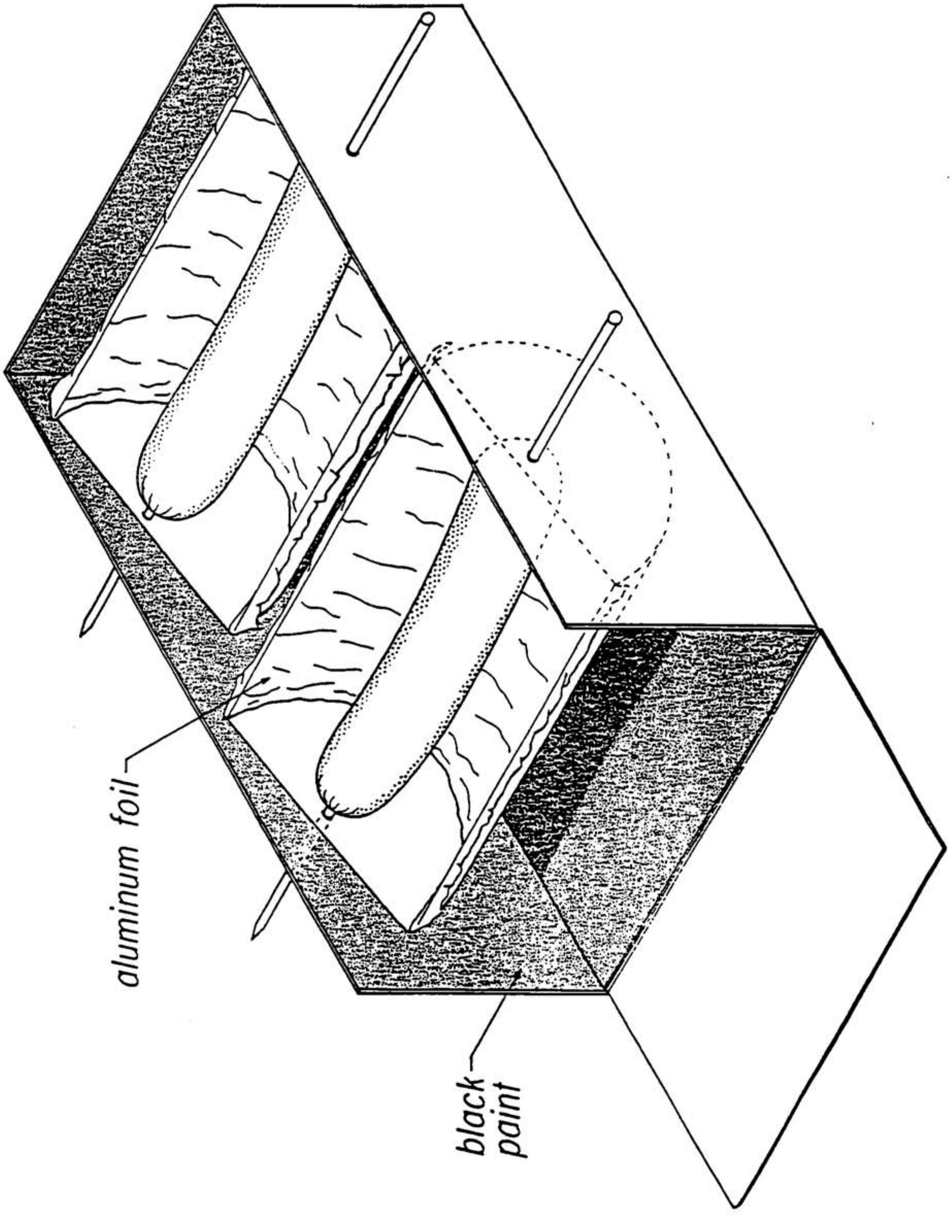
DAY FOUR

1. Have students write a comparison of actual times vs. predictions.
2. Using graphs from Day Three, have each group plot actual cooking times (using a different color to visually show results).

Construction:

1. Cut salt box in half lengthwise. Cover with foil, shiny side facing out.
2. Cut one end of shoebox (see illustration).*
3. Paint the inside of shoebox black.
4. Put skewer through one side of shoebox and salt box, put food on skewer, take skewer out the other side of boxes (see illustration).
5. Cover top of boxes with plastic wrap.
6. Set in sun. (Note: Ants **will** be a problem; you might try enclosing your entire work area by drawing a perimeter with insect chalk, which is available in Oriental grocery stores.)
7. Approximate cooking time for hot dogs is about 25 minutes; for marshmallows, which can be messy, 15 minutes. (Note: These times are based on conditions in Tucson, Arizona in April!)

*If you have a very long shoebox, you might want to cut the long side of the shoebox and arrange the salt boxes side-by-side.


aluminum foil
black paint

EXPERIMENT L

Three States of Matter

Integration:

Process Skills: Measuring, predicting, observing

Objectives:

Students will observe that matter can exist as a solid, a liquid, or a gas.

Relate this experiment to the sections about Jupiter, Saturn, Uranus, Neptune, Pluto, and comets in *Our Solar System* (grades 2–5 version).

Materials:

1. Ice cubes, dry ice, ice chest or cooler
2. Two glass jars
3. Pan balance
4. Two balloons
5. Empty soda can
6. Large blob of clay
7. Tongs or heavy potholders
8. Beaker

Procedures:

PART ONE

1. Place an ice cube in a glass jar. Pass it around the class for observation. Note the appearance of a liquid in the jar after a few hands have touched the jar. Look for evidence of condensation (a "cloud" forms) above the ice when blowing on it, and the appearance of moisture on the outside of the glass.

2. Discuss what happens to the ice. If the ice cube is completely melted, would the liquid still weigh the same as the ice cube did?

3. Repeat the experiment with another ice cube. Place the ice cube in a jar. Put the jar on a pan balance, balance it, and determine whether it is still balanced after the ice cube melts.

PART TWO

1. Place a piece of dry ice in a glass jar. Pass it around for inspection. **WARNING:** do not touch the dry ice or throw it from the jar! Note the lack of liquid as the dry ice gets smaller. Look for evidence of condensation by blowing on the dry ice.

2. Discuss what happens to the dry ice. It disappears, but it does not melt. Melting is the term used when a solid changes into a liquid. Where does the dry ice go?

3. Repeat the experiment with another piece of dry ice. Place the dry ice in a jar. Put the jar on a pan balance, balance it, and determine whether it is still balanced after the dry ice is gone.
4. Explanation: Dry ice is frozen carbon dioxide. It does not melt; it turns directly into a gas (carbon dioxide vapor) at room temperature and pressure. This process is called sublimation. The gas escapes from the open jar.
5. Predict what will happen if ice is put into an uninflated balloon and the balloon is tied shut. Would the same thing happen if dry ice is used? Try both experiments.
6. Why does the balloon with the dry ice inflate itself? What is inside the balloon after the dry ice has disappeared?

PART THREE

1. How can you change water (a liquid) into water vapor (a gas)? Evaporation is the term that describes a liquid changing into a gas. Water evaporates slowly at room temperature, but you can speed up this process by heating the water.
2. Put a small amount of water in an empty soda can; heat the can until the water boils. Steam may be visible at the top of the can. This is not water vapor, but water droplets condensing in the cooler air.
3. Hold an ice cube near the top of the can to see more condensation. Water vapor is an invisible gas, now filling the can.
4. Using tongs or potholders, remove the can from the heat and quickly plug the top opening with a large blob of clay. Set the can in a jar of ice cubes and observe. What makes the can collapse?
5. Explanation: The water vapor has replaced the air in the can. As the vapor cools, it condenses into water. The clay prevents air from re-entering the can. The gas pressure inside gets lower than the air pressure outside. Eventually the air pressure is strong enough to crunch the can. Air pressure is about 15 pounds per square inch.

Terms to know:

boil: when a liquid bubbles and turns rapidly into a gas.

condense: when a gas turns into a liquid.

evaporate: when a liquid turns into a gas.

freeze: when a liquid turns into a solid.

gas: matter that fills its container and exerts a pressure in all directions.

liquid: matter that flows and needs walls to prevent it from spreading.

melt: when a solid turns into a liquid.

solid: matter that retains its own shape.

states of matter: solid, liquid, or gas.

sublime: when a solid turns into a gas, or a gas turns into a solid.

ACKNOWLEDGMENTS

Planetary Poetry:	Based on NASA booklet *Using Art to Teach Science*
Ellipses:	Karen Swarthout
Planetary Mythology:	Authors
Humans in the Martian Environment:	Authors
Global Astronomy:	Based on activity by Sue Garrison
Scale Model Solar System:	Authors
Graphing the Solar System:	Authors
Solar System Reports:	Based on activity by Linda Powers
Moon Journal:	Larry Dunlap
Daytime Astronomy—Shadow Observations:	Larry Dunlap
Solar Cookers:	Lesson plan—Jonathan Becker Construction—Linda Brown
Three States of Matter:	Larry Dunlap

Your assistance in helping us evaluate *Our Solar System* materials will be invaluable in planning future materials and workshops.

1. How did you receive the materials?
    - From a NASA Regional Teacher Resource Center ☐
    - From another teacher or principal ☐
    - By attending a workshop ☐

2. Which material(s) did you use?
    - Video ☐
    - Booklet (grades K–3) ☐
    - Booklet (grades 2–5) ☐
    - Teacher's Guide and Activities ☐

3. Which activities did you use?
    - Booklet challenges ☐
    - Design a Planet ☐
    - Planetary Poetry ☐
    - Ellipses ☐
    - Planetary Mythology ☐
    - Humans in the Martian Environment ☐
    - Global Astronomy ☐
    - Scale Model Solar System ☐
    - Graphing the Solar System ☐
    - Solar System Reports ☐
    - Moon Journal ☐
    - Daytime Astronomy—Shadow Observations ☐
    - Solar Cooker ☐
    - Three States of Matter ☐

4. What changes would you make to *Our Solar System* materials?

5. What topics would you like to see included in future written and/or video materials?

6. Did you modify any of the activities to meet the specific needs of your class? If so, we would appreciate a description.

Name ______________________________
Address ______________________________
Grade(s) taught ____________________

Comments:

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STAMP

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Additional Comments: