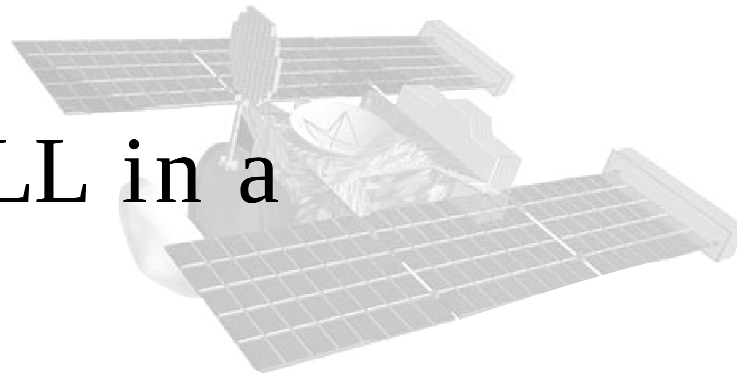
Think SMALL in a Big Way



This section contain the basics on the small bodies of the Solar System, their significance, and reasons you, the teacher, should find small bodies worth teaching in the classroom. You will also find overviews of upcoming missions. The activity in this section deals with a few of the reasons small bodies are important:

- **Comet Cratering -** Models crater formation. Impacts on Earth can create craters and affect ecosystems (possibly including the extinction of the dinosaurs).

Comet Wild 2 was chosen for the STARDUST mission because it is “pristine.” The fewer times a comet has traveled near the Sun, the closer it is to its original state back when the Solar System formed. Each time a comet travels through the inner Solar System, it loses more of its original gases and dust as it passes by the Sun. Comet Wild 2 will only have made five orbits around the Sun by the time the STARDUST spacecraft reaches it, hence its “pristine” condition.

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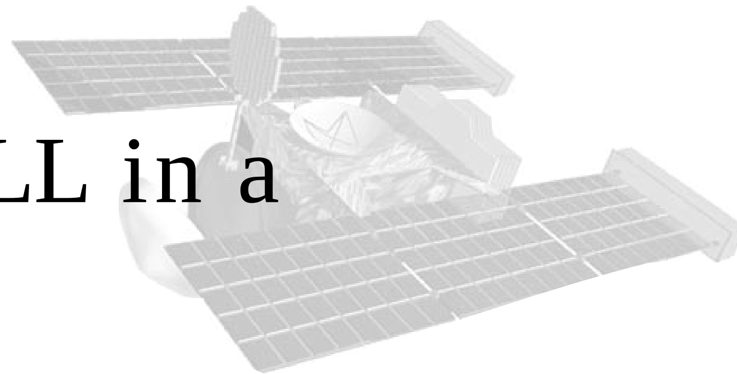
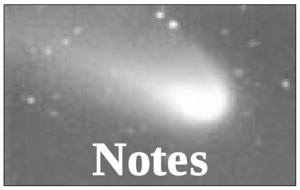


Our Solar System may have a star, nine planets, and a few dozen moons, but often overlooked are the billions of small bodies that orbit the Sun. Comets, asteroids, and meteoroids, ranging in size from a grain of sand to a large state, have recently begun to receive a lot of attention. What they lack in mass they make up for in style: meteoroids can produce spectacular meteor showers, asteroid impacts can shape the topography of planets, and one of nature's most breathtaking phenomena can be a comet sporting a long, elegant tail.

Why Study Small Bodies?

Although generally overlooked, small bodies make big impacts in the Solar System and can leave a lasting impression on students as well. There are a number of compelling reasons why scientists study small bodies:

- Because they are among the oldest objects in the Solar System, small bodies can help us understand how the Solar System was formed and evolved.
- Impacts from comets may have deposited material that contributed to the formation of the oceans and atmospheres on some planets, including Earth.
- Some people believe that life may have its roots in the chemical compounds that are found in comets.
- Small bodies have left craters on all of the terrestrial planets and moons, and the Earth is no exception. There are dozens of identifiable craters on our planet, some as large as 140 kilometers across! Hundreds of objects must have hit the planet in the past, but erosion has obliterated all but the largest or most recent craters.
- Impacts can affect climate and ecosystems on a global scale. Some scientists theorize that an impact by an asteroid or comet over 10 kilometers in diameter was responsible for the extinction of the dinosaurs. Astronomers today track near-Earth asteroids as they trek through the Solar System, and are constantly discovering new ones. Many scientists believe that Earth will be hit by a small body again sometime in the future.



"SMALL Bodies' Big Impact"

Asteroids

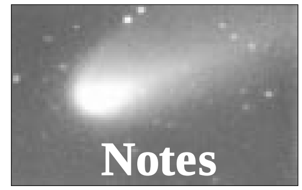
Small bodies of the Solar System are divided into three categories: asteroids, comets, and meteoroids. Asteroids are metallic, rocky bodies that orbit the Sun and range in size from 1,000 kilometers in diameter down to the size of pebbles. Asteroids are thought to be material left over from the formation of the Solar System that was prevented by Jupiter's strong gravity from forming a planet-sized body. It is estimated that the total mass of all asteroids would comprise a body approximately 1,500 kilometers in diameter (less than half the size of the Moon). Most asteroids are found in the asteroid belt, an area between the orbits of Mars and Jupiter. Astronomers believe that there are over 100,000 objects in the belt. However, asteroids exist in locations throughout the Solar System. Trojan asteroids orbit 60 degrees ahead of and behind Jupiter, held in place by the gravitational tugs of the Sun and the planet. Asteroids whose orbits bring them within the orbit of Earth are called near-Earth asteroids (NEAs). The Apollo asteroids are examples of NEAs. Asteroids can be grouped into three categories: carbonaceous, which comprise 75% of known asteroids and inhabit the main belt's outer region; silicaceous, which dominate the inner asteroid belt and comprise 17% of known asteroids; and metallic, in the middle region.

Comets

Comets are only a few (1-20) kilometers in diameter and are made of ices and rock. They usually have orbits that are long and elliptical compared with most asteroids. Comets originate at the outer edges of the Solar System. When a comet is far away from the Sun (beyond the orbit of Jupiter), its *nucleus* (the solid part of the comet) remains frozen and changes very little. As it approaches the inner Solar System, however, the volatile ices of the nucleus begin to *sublimate*, or change directly from a solid to a gas. The gases and dust released from the comet form a *coma* around its nucleus, which can grow to become 100,000 kilometers in diameter and usually grows in size and brightness as the comet approaches the Sun. The Sun's radiation pressure and solar wind accelerate materials away from the coma at differing velocities according to the size and mass of the materials. Thus, two tails are formed-one of dust and one of gas. A tail may extend to millions of kilometers from the head. Each time a comet approaches the Sun, it loses some of its volatiles; eventually becoming just another rocky mass in the Solar System.

Meteoroids

Meteoroids are different from comets and asteroids chiefly in size. They are very small, usually only a few centimeters to a few meters in diameter. Meteoroids are believed to be pieces of asteroids left over from collisions with other asteroids, as well as grains of dust ejected from comets. We are most familiar with meteoroids when they enter Earth's atmosphere. The particles are heated by friction, creating a streak of light against the night sky. This phenomenon is known as a *meteor*. A *meteor shower* occurs when Earth passes through the leftover dust from the tail of a comet. During showers, the number of meteors witnessed can increase from just



a couple to over 50 an hour. If a piece of the original meteoroid survives its journey and reaches Earth, it is called a *meteorite*. Most meteorites are discovered long after they have hit Earth. A few are seen falling and are collected immediately. Some of the most successful meteorite collecting occurs in Antarctica, where shifting ice concentrates meteorites in certain areas and the dark rocks contrast well with the white terrain. Meteorites are difficult to classify, but the three broadest groupings are stony, stony iron, and iron. Chondrites, which are stony meteorites, are the most common and radiometric dating has placed them at the age of 4.55 billion years (approximately the age of the Solar System).

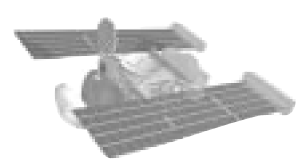
Upcoming Missions

The awe inspired by small bodies is infused in the scientific community as well. Scientists have recently recognized these small bodies as an important puzzle piece for understanding the formation and evolution of the Solar System. As a result, six spacecraft will rendezvous with at least ten different small bodies over the next several years:

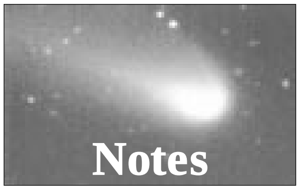
- NEAR, launched in 1996, will perform the first scientific survey of near-Earth asteroids in the years 1997-1999.
- *Muses-C/Muses-CN*, to be launched in early 2002, will send a rover to explore and sample Asteroid 1989 ML and return fragments of the asteroid’s surface for further detailed analysis.
- *Deep Space 1*, primarily a platform to test new instruments for future missions, will encounter Asteroid 1992 KD in 1999, and Comets Wilson-Barrington and Borrelly if the mission is extended.
- *Contour* (Comet Nucleus Tour) will assess comets for their diversity, encountering Comets Encke, SW3, and d’Arrest in 2003-2008.
- STARDUST, launched in February 1999, will rendezvous with Comet Wild 2 in 2004 and become the first spacecraft to sample cometary dust and return it to Earth for analysis.
- Rosetta is a cometary mission that will be launched in 2003 by Ariane 5. Rosetta will rendezvous with comet Wirtanen and orbit it, while taking scientific measurements.
- Deep Impact will send a 500 kilogram impactor to blast a crater into a comet nucleus, revealing the never-before-seen materials and structure of the interior of a comet.

What we learn about them is expected to reshape our understanding of how our Solar System-and perhaps even how life-formed.

STARDUST



STARDUST is the fourth of several flight missions in NASA’s Discovery program. The goal of the Discovery program is to design small, less expensive spacecraft with specific scientific goals that can be built in 36 months or less. *Mars Pathfinder* and *Lunar Prospector* are examples of Discovery missions chosen in the past.

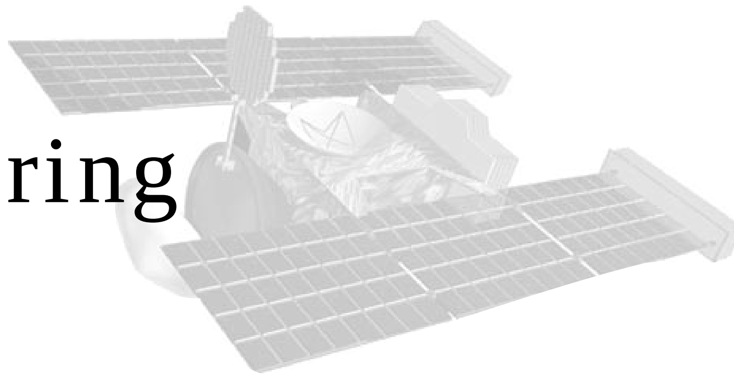


The spacecraft was launched in February 1999 on board an expendable launch vehicle and rendezvous with Comet Wild 2 in January 2004, coming within 150 kilometers (93 miles) of the comet's nucleus. The spacecraft will be the first ever to collect dust spewed from a comet and return it to Earth for detailed analysis. The comet samples are made up of ancient pre-solar interstellar grains and material that condensed in the solar nebula, a diffuse cloud of gas and dust from which the Sun and planets formed. A sample return capsule will reenter Earth's atmosphere and land on a dry lake bed in Utah in January, 2006. For more information on STARDUST, see the STARDUST Mission Fact Sheet.

Key STARDUST Dates

1974	Comet Wild 2 orbit altered by Jupiter, bringing it into the inner Solar System in pristine condition
January 1978	Paul Wild discovers Comet Wild 2
1995	NASA selects STARDUST mission
February 1999	STARDUST Launch
January 2000 - May 2000	First Interstellar Dust Collection
January 2001	Earth flyby
July 2002 - December 2002	Second Interstellar Dust Collection
January 2004	Wild 2 Encounter
January 2006	Sample Return Capsule returns to Earth

Comet Cratering



Overview

Students will discover what happens when impactors hit the surface of a planet using balls of different sizes, flour and cocoa. If a large enough comet impacted Earth, the result could affect ecosystems. Some scientists theorize that a large comet or asteroid impacted Earth millions of years ago, leading to the extinction of the dinosaurs.

Objectives

- Create impact craters.
- Describe the relationship between the size of the crater and the size, speed, and distance of the impactor.
- Observe and record how light at various angles shadows craters and highlights relief.
- Estimate the age of a planetary surface.

Preparation

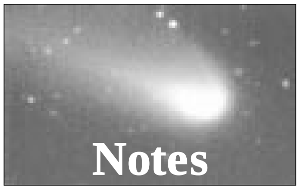
1. Read through the lesson and try out this activity yourself before doing it with students.
2. Make a transparency of the picture of the Barringer Meteor Crater on page 191.
3. You may want to put one careful student in charge of passing out the flour to each of the groups or prepare trays ahead of time. Demonstrate how to put a thin layer of the dark powder on top of the flour using a flour sifter.
4. Discuss types of surfaces and surface layers on Earth.

Timeline

1 to 2 class periods

Key Question

What can you learn by studying craters on a planetary surface?



Materials

- ❑ Flour or mortar powder
- ❑ 1 cup of hot chocolate powder or cocoa
- ❑ A flour sifter
- ❑ A kitty litter box or pizza box lid
- ❑ Garbage bags
- ❑ 3 rulers
- ❑ Various sizes of balls (marbles, golf balls, etc.)
- ❑ 1.5 meters of string per team
- ❑ Scissors
- ❑ Chair
- ❑ Drop cloth or newspaper
- ❑ Safety goggles for each team member
- ❑ Overhead projector
- ❑ Transparency sheet with images of Barringer Crater and Mimas

Management

This activity is messy. Be sure to have floor coverings or make the craters outside. Students can measure the diameter of each ball by putting the ball between two rulers and measuring the distance between the rulers.

CAUTION: Students should wear safety goggles when making craters to prevent ejecta from getting into their eyes. Also students should be careful when standing on top of chairs.

When looking at the crater images, make sure students understand that crater floors sometimes look deeper than they really are because of the shadowing effects of various light sources on craters, which they will study in the second part of this lesson.

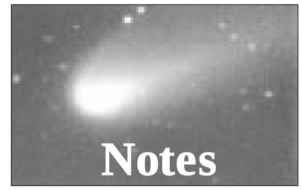
Procedure

1. Ask students what they know about comets. Find out why they think it is important to study comets. Write down their responses on the chalkboard. They might hit on reasons mentioned in Think SMALL in a Big Way on page 3. If not, lead them toward the question, “What would happen if a comet hit Earth?”

   Depending on the size of the comet nucleus and a few other factors, the comet may never get through Earth’s atmosphere, or it could impact and create a crater. A really big crater caused by a comet more than 10 kilometers in diameter is thought to possibly have lead to the extinction of the dinosaurs.

2. Ask the class if they know how craters are formed. Tell them that they will find out by conducting an experiment.

3. Explain how students will work together in teams of four or five.
4. Coach and facilitate the activity, asking Reflection Questions throughout.
5. Have the reporter for each group explain and discuss the group's results.
6. Place the transparency of Barringer Crater and Mimas, a moon of Saturn, on the overhead projector. Keep Mimas covered with a piece of paper. Have students identify the parts of Barringer Crater.
7. Show Mimas. Have students explain what they think happened. Scientists speculate that whatever hit Mimas probably came close to disintegrating this moon.
8. Follow up with Reflection Questions.



Reflection Questions

1. Name several ways that simulating cratering in the classroom differs from real impacts.
2. What kinds of objects in the Solar System make craters?
3. Give three reasons why scientists use models.

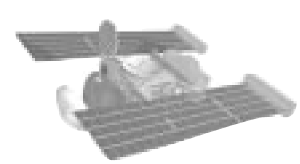
   NOTE: In addition to using models to study impact craters, scientists have also used real explosions. Early work on cratering included the examination of bomb craters, including some the size of the Meteor Crater, also known as the Barringer Meteor Crater. Scientists also use high-speed guns to make simulated craters, and they observe real craters to gain further insights.
4. What determines the size of a model crater?

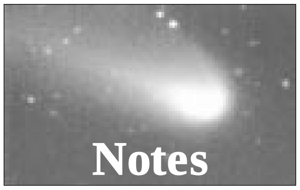
   NOTE: Again, remind students that it is the speed of the impactor, and not the distance, that is important in real cratering. Only in the classroom does distance have a noticeable effect on craters.

Worksheet Answer Key

Answers will vary depending on the size of the impactors chosen.

1. The surface is smooth, level, and uniform, with a dark layer over a light layer.
2. Answers will vary depending on ball sizes.
3. & 4. Chart data will vary; however, data should indicate that the larger the height, the larger the crater, and the larger the impactor, the larger the crater. The graph should reflect this trend.
5. The larger the impactor, the larger the crater.
6. The taller the height, the bigger the crater.
7. Answers will vary. For us, the craters were roughly 1.5 to 2 times as big as the impactor.
8. Answers will vary, but drawings should show a crater with all parts labeled.
9. When impactors slam into planets, they cause rock and dust from deeper layers of the planet's surface to mix with the top layer. The flour represents the deeper layers of the planet, and the cocoa represents the surface layer.





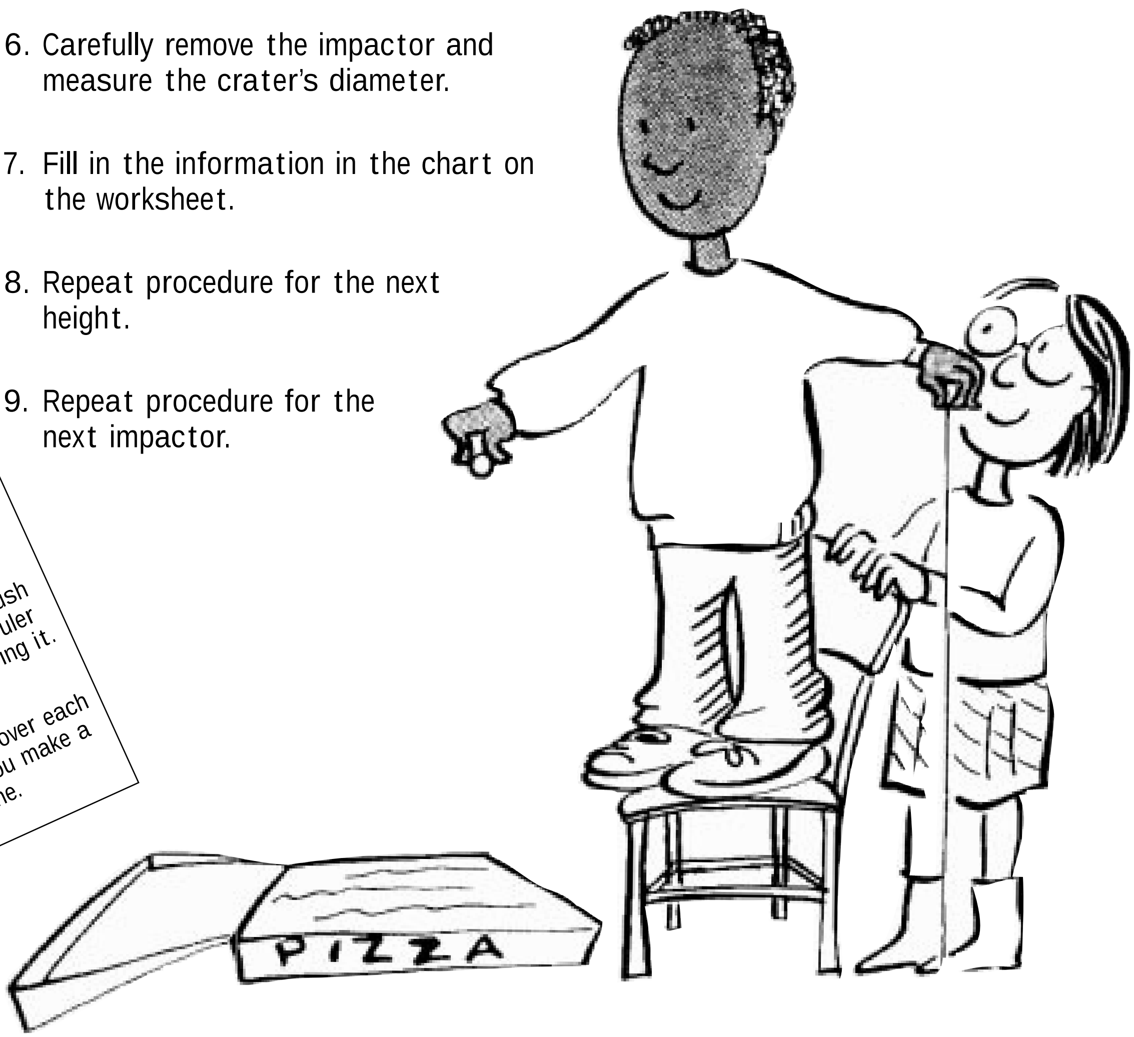
Crater-Making Procedure

Follow these steps to make craters.

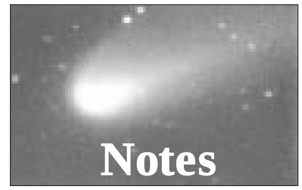
1. Make sure the string is 1.5 meters in length.
2. Measure the diameter of each of your impactors.
3. Take team positions, with the dropper standing on the chair and the material specialist spotting the dropper.
4. Have the reporter check the height of the string and make sure the setup is correct.
5. Drop the first impactor from the first height.
6. Carefully remove the impactor and measure the crater's diameter.
7. Fill in the information in the chart on the worksheet.
8. Repeat procedure for the next height.
9. Repeat procedure for the next impactor.

Tips

- Remove the impactor carefully before measuring diameter.
- Be careful not to crush the crater with the ruler while you are measuring it.
- Do not smooth over each crater before you make a new one.



Comet Cratering Worksheet



Team ______________________________ Date ____________

____

____

____

____

Your Mission

Your mission is to make craters and examine them closely. What you learn about craters will help you tell a story about the life of the planets and moons in the images.

Roles

Decide which role each team member will assume:

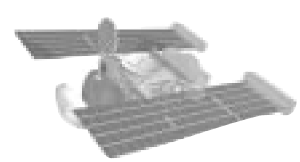
- Dropper: drops impactors on the surface at the direction of the recorder.
- Material Specialist: is in charge of setting up materials and safety.
- Measurer: measures impactors and crater diameters.
- Recorder: writes down group answers and checks that calculations are done correctly.
- Reporter: closely examines impacts and speaks to the class for the team.

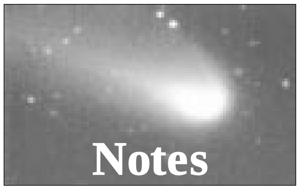
Setup

1. Lay down the drop cloth or newspaper.
2. Place the tray in the middle and fill the tray 3 inches (about 8 centimeters) high with flour.
3. Sprinkle a THIN layer of hot chocolate powder on top using a flour sifter.
4. Move a chair close to the tray.
5. Gather the impactors, string, and rulers.

Materials

- ❑ Flour or mortar powder
- ❑ 1 cup (8 ounces) of hot chocolate powder or cocoa
- ❑ A flour sifter
- ❑ A kitty litter box or pizza box lid
- ❑ Garbage bags
- ❑ 3 metric rulers
- ❑ Various sizes of balls (marbles, golf balls, etc.)
- ❑ 1.5 meters of string per team
- ❑ Scissors
- ❑ Chair
- ❑ Drop cloth or newspaper
- ❑ Safety goggles for each team member
- ❑ Overhead projector





Crater Making

1. Observe the setup of your testing field.
   What does the surface look like?

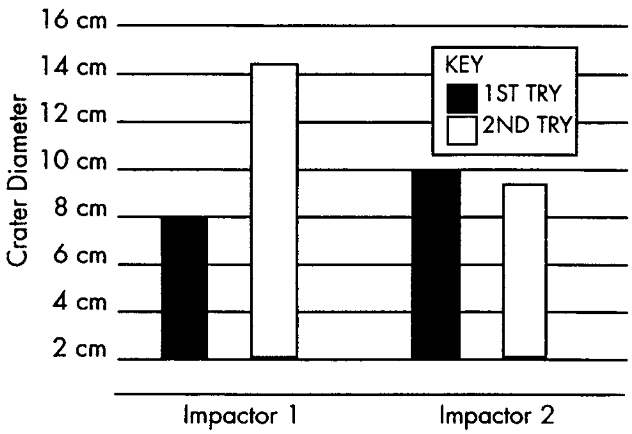
2. Put two rulers on either side of an impactor and use the third ruler to measure the distance between them. This is the width or diameter of the impactor. Measure the diameter of all three impactors.

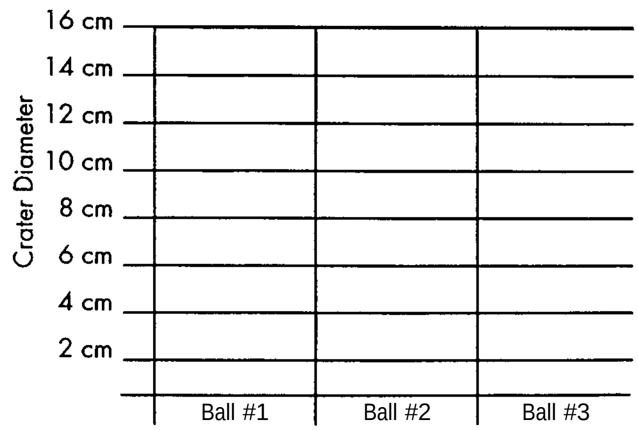
Ball 1 is ________ cm. Ball 2 is ________ cm. Ball 3 is ________ cm.

3. You will now make craters by following the directions on the Crater Making

	Height		Crater Diameter
Ball 1 diameter ______ cm	1st try 2nd try	30 cm 1.5 meters	____________ ____________
Ball 2 diameter _____ cm	1st try 2nd try	30 cm 1.5 meters	____________ ____________
Ball 3 diameter _____ cm	1st try 2nd try	30 cm 1.5 meters	____________ ____________

Procedure Sheet.





4. Graph the results on a bar graph, following this example:

5. How did the size of the impactor change the size of the crater?

____

6. How did different heights change the size of the crater?

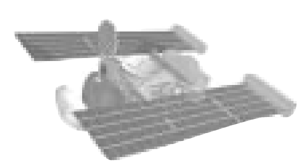
____

7. Pick two different craters. How much bigger is the crater than the impactor?

$\frac{\text{Impactor Size}}{\text{Crater Size}}$ = ____________ = ____________

$\frac{\text{Impactor Size}}{\text{Crater Size}}$ = ____________ = ____________

8. Pick the best crater in your tray. Draw what it looks like and label the parts.



9. Look at your best crater. Notice the mixture of flour and cocoa.
What does this mixture tell us about what craters do to the surfaces of planets?