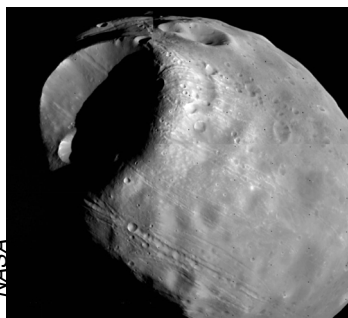


Cosmic Chemistry: Planetary Diversity

Ouch! That Hurts!

TEACHER GUIDE

BACKGROUND INFORMATION



Craters on surface of Mars' moon Phobos.

Before Galileo turned his telescope to the sky, people thought that celestial objects were perfectly smooth and without flaw. Galileo found that this was not true. The moon was full of craters and far from smooth. This changed the core belief about the universe.

Impact cratering is a field of study that has been actively pursued only during the last few decades. The recent increased interest in planetary cratering is largely due to the advent of space travel, and in particular, to the Apollo program.

Spacecraft images show that most of the solid surfaces of planets and satellites are scarred by many impact craters. Photographs of these craters can be found in most recent solar system publications, including NASA's Web sites and their CD-ROM, Planetary Data System [see [References, Resources, URLs, CD ROMs](#) in this module].

In some cases, impact craters are the dominant landform. Some appear to be recent, having crisp rims and bright rays. These rays are great streaks of debris ejected from the crater that has fallen back to the planet's surface. Others show evidence of being heavily battered, with broken rim segments.

The size of a crater depends upon the velocity and angle at which the incoming projectile impacts a planet's surface and on the composition of both the projectile and the planet's surface, among other factors. After impact, the crater's size may be modified by loose debris sliding down the interior walls and gathering on the floor of the crater's depression.

Degradation of impact craters can result from:

- Impacts on airless bodies, like the Earth's moon, resulting in a surface that is crowded with craters.
- Volcanism, which creates surfaces that are more sparsely cratered by covering old craters with lava.
- Wind, water, and tectonic processes that erase craters shortly after they are formed. The surfaces of the Earth and Mars show evidence of these processes.

Most studies of impact cratering have focused on those on the surfaces of our moon, Mars, and Mercury. For this reason, in the first part of the activity, students will design a method for testing the size and shape of an impact crater made by a variety of projectiles landing at different angles on different types of surfaces, such as a gel or colloid (an aqueous mixture of a gelatin food product or corn starch), a relatively fluid surface (perhaps wet and dry sand), and a more solid surface (like clay or pumice).

This activity also focuses on the role that atmospheric gases play in the cratering process. A planet's atmosphere has a two-fold effect on the formation of impact craters: the first is related to the projectile's flight through the atmosphere; and, the second involves interaction of the vapor and ejecta from the crater with the ambient atmosphere.

In the second part of the activity, students will be using a mathematical equation that will allow them to determine whether or not a meteorite of a given size, composition, and velocity could penetrate the atmospheres of Venus, Earth, or Mars.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

[Science As Inquiry](#)

Abilities necessary to do scientific inquiry
 Understandings about scientific inquiry

Physical Science

Properties and changes of properties in matter
 Motions and forces
 Transfer of energy
 Interactions of matter and energy

History and Nature of Science

Science as a human endeavor
 Nature of science and scientific knowledge

Grades 9-12Science As Inquiry

Abilities necessary to do scientific inquiry
 Understandings about scientific inquiry

Earth and Space Science

Earth in the solar system
 The origin and evolution of the universe
 Energy in the Earth system

Physical Science

Properties and changes of properties in matter
 Motions and forces
 Transfer of energy
 Interactions of matter and energy

History and Nature of Science

Science as a human endeavor
 Nature of science and scientific knowledge

(View a full text of the [National Science Education Standards](#).)

MATERIALS

For each student:

- Copy of [Student Activity, "Ouch! That Hurts!"](#)
- Copy of [Student Text, "Ouch! That Hurts!"](#)

For each group:

- 1 steel ball, 1 small stone, and 1 piece of ice
(These should be approximately the same size—about 1.5 cm across—but it is not necessary that they be spherical in shape.)
- 3 or 4 disposable metal pans (20 cm x 20 cm), trays or similar flat, shallow containers. These should be filled with at least a 4-5 cm layer of "surface" materials such as gelatin, cornstarch, white sand with cinnamon top layer, clay, or pumice.
- Water
- Metric ruler
- Calculator
- Stream Table (optional)

Optional Activity

Ask one group of students to add water to sand and/or clay until it is saturated and there is a layer of water on top to simulate a large lake or ocean. Have them repeat the Part I instructions to observe any differences water makes in impact cratering. Once students have modeled cratering in wet sand, they can model erosion of craters by using a stream table. Ask students "What planet(s) might this have occurred on?"

PROCEDURE

1. Before class collect the materials necessary for the activity and make copies of the following handouts:
 Student Activity, "Ouch! That Hurts!"
 Student Text, "Ouch! That Hurts!"
2. Prepare in advance:
 - a) Gelatin (preferably unflavored) according to the directions on the package (at least 12 hours before using).
 - b) Cornstarch colloid one day before using. For every cup of cornstarch, add approximately 0.5 cup of water slowly. Mix by stirring, either by hand or with a spoon, until it "flows" through your fingers. Cover to prevent water evaporation.

3. Divide the class into teams of two or more students. Ask them to select a leader and a reporter in each group. The leader will assign specific responsibilities to each team member. The reporter will be responsible for recording the team's results.
4. Distribute copies of the Student Activity, "Ouch! That Hurts!" to each student and the materials listed for each team.
5. Instruct students to carry out the Part 1 instructions of the Student Activity, "Ouch! That Hurts!" using all the "targets" and "surface materials" that you have provided.
6. Start the next period's class discussion of students' observations with questions similar to the following:
 - a) What differences did the groups observe when they used ice and a small stone rather than the steel ball as the "projectile"?
 - b) What differences did the groups observe when they aimed the same "projectile" at different types of surfaces?
 - c) What differences did the groups observe in the impact zones when the projectiles collided with the surfaces at different angles?
 - d) What differences did the group conducting the optional activity observe using water covered surfaces from those observed by other groups?
7. Have groups reform and ask them to summarize the variables that appeared to make a difference in impacts on the surfaces used.
8. Distribute copies of the Student Text, "Ouch! That Hurts!" to students when they have finished their drawings and answers to Part 1 questions and summary.
9. Part 2 should be assigned as individual or team homework for the next class period.
10. Start the next period's class discussion with questions regarding impact cratering, using questions similar to the following:
 - a) How does the density of a planet's atmosphere affect the number of possible meteoroid impacts on the surface?
 - b) How does the density of a planet's atmosphere affect what happens to the meteoroid before impact? How does this affect the type of crater formed on impact?
 - c) Do you think the majority of craters on terrestrial planets with atmospheres would be made by meteoroids impacting at 90° angles or at angles closer to 45°? Why do you think so?
 - d) Predict which angle of impact might produce the most ejecta to interact with the atmosphere? Explain your answer.
 - e) What predictions did you make regarding the number of impact craters on Venus?
 - f) What predictions did you make regarding the difficulty meteoroids might have in entering the atmospheres of the giant planets?

Teaching Tip

One teacher asked the students to use rulers to "launch" their projectiles so the velocity and angle would be more accurate.

Alternate Strategy Tip

Once students have made their prediction for 10 d, ask them to develop a test in which they test their prediction. They should come up with many ways to do this. One possible test would be to use stones sand and masking tape. The stone would represent the meteorite, the sand would represent the Earth, and the tape would collect the ejecta. One piece of tape could be used per trial at different angles.

Alternate Strategy Tip

Ask students to observe images of the four Galilean moons of Jupiter. Have them compare the amount of cratering on each moon and ask them to predict the reason for the differences in the amount of cratering. Interested students could research each of the moons for further study.

After reading the Student Text "Ouch! That Hurts!" students will want to ask questions about the Shoemaker-Levy 9 collision with Jupiter. Possible questions that scientists have include: What was the size of the comet fragments? Were they large or small? How deeply did the comet pieces penetrate into Jupiter's atmosphere before exploding? What caused the immense black patches to remain in Jupiter's atmosphere?

- g) How can we summarize the relationship between a planet's atmosphere and its surface impact cratering?