All About Craters

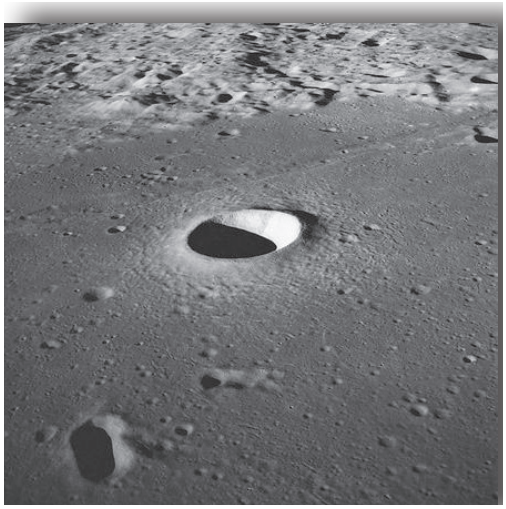
For Team Members:

The goal of this activity is to provide team members with a 20-45 minute activity to do in a formal school setting or informal public group meeting at which you have been asked to present information about the mission as well as perform a hands-on activity. Over time, OSIRIS-REx will develop detailed, original activities for team members and teachers to use. Currently, we have these time-tested fun, hands-on activities for your use. The design of this activity also allows teachers to review objectives and connections to content standards. While your role is focused on performing the activity, the teachers may find the connection to standards and the "lesson format" helpful. This activity can be completed with students in smaller groups or as a demonstration, with all students watching the presenter.

Warning: This activity can get messy.

All about Craters

The circular features so obvious on the Moon's surface are impact craters formed when impactors smashed into the surface. The explosion and excavation of materials at the impacted site created piles of rock (called ejecta) around the circular hole as well as bright streaks of target material (called rays) thrown for great distances. We are familiar with the craters on the moon, and with new space missions, scientists know that asteroids, comets, and moons around other planets all have craters.



Moltke crater was observed by the crew of the Apollo 10 mission which orbited the moon

Image Credit: NASA

Two basic methods that form craters in nature are: 1) impact of a projectile on the surface and 2) collapse of the top of a volcano creating a crater termed caldera. By studying all types of craters on Earth and by creating impact craters in experimental laboratories, geologists concluded that the Moon's craters are impact in origin. The factors affecting the appearance of impact craters and ejecta are the size and velocity of the impactor, and the geology of the target surface.

By recording the number, size, and extent of erosion of craters, lunar geologists can determine the ages of different surface units on the Moon and can piece together the geologic history. This technique works because older surfaces are exposed to impacting meteorites for a longer period of time than are younger surfaces. Impact craters are not unique to the Moon. They are found on all the terrestrial planets and on many moons of the outer planets.

Meteor Crater, outside of Flagstaff, Arizona, is the remains of an impact caused by a meteorite 50 meters across almost 50,000 years ago

Image Credit: D. Roddy.

On Earth, impact craters are not as easily recognized because of weathering and erosion. Famous impact craters on Earth are Meteor Crater in Arizona, U.S.A.; Manicouagan in Quebec, Canada; Sudbury in Ontario, Canada; Ries Crater in Germany, and Chicxulub on the Yucatán peninsula coast in Mexico.

For more information on craters and impacts, visit:

http://www.purdue.edu/impactearth/

www.greatballsoffireexhibit.org

http://www.solarviews.com/eng/tercrate.htm

http://nineplanets.org/meteorites.html

Chicxulub (Pronounced: *chicks + a + lube*) is considered by most scientists to be the source crater of the catastrophe that led to the extinction of the dinosaurs 63 million years ago. An interesting fact about the Chicxulub crater is that you cannot see it. Its circular structure is nearly a kilometer below the surface scientists found it after they examined magnetic and gravity data.

The OSIRIS-REx mission will visit asteroid 1999 RQ36 during its mission. The spacecraft will launch in 2016, and after traveling millions of miles, it will rendezvous with the asteroid in 2019. While at the asteroid, the spacecraft will take detailed images of the surface, gathering valuable data for scientists to analyze. The spacecraft will move down toward the surface of the asteroid and grab a sample of the asteroid to bring back to Earth for scientists to study in their laboratories. The spacecraft will once more travel millions of miles back to Earth to return the sample in 2023. Scientists will look at the organic compounds contained in the sample to help revolutionize our understanding of life in the Solar System!

This image of Asteroid Eros shows many craters, which were the result of many collisions in its history

Image Credit: NASA

Asteroid 1999 RQ36 is about 500 meters (1/3 of a mile) wide and has one of the highest probabilities of colliding with the Earth late in the 22nd century. The OSIRIS-REx mission will seek to provide scientists with important measurements to determine the likelihood of asteroid impacts, providing us with a foundation to begin developing techniques to prevent such hazards. If an impactor the size of 1999 RQ36 were to collide with Earth, it would leave a crater almost 6 miles wide – that's almost 8 times wider than Meteor Crater! But remember – almost 75% of the Earth is covered with oceans, which means most impactors, whether big or small, land in the ocean. A large impactor hitting the ocean could cause a tsunami for the nearest coastline.

Objective

Participants will understand the physics of a crater, noting how the mass and height of an impactor (meteor) affects the size and shape of the crater.

The presenter will sum up the importance of understanding craters (formation, cause, physics, etc.) - their connection to our life on Earth (dinosaur extinction/rise of mammals), the OSIRIS-REx mission to 1999 RQ36, and asteroids in general. The OSIRIS-REx mission will be able to study the early Solar System as it is preserved on 1999 RQ36, and as a result, provide insight into the formation of the Earth and the building blocks of life. The mission will also study orbital measurements such as the Yarkovsky effect which affects impact probabilities and life on Earth.

Materials

The following materials will be used for impacting and charting results

- Photos of craters (included at the end of the lesson)
- Balance or small scale
- 2 impactors (of different densities)
- Meter stick
- Ruler (plastic, with middle depression)
- protractor
- "Data Chart" (on page 4) for each impactor
- Graph paper

The following materials will be used to simulate an asteroid's surface

- 1 large foil rectangular pan (22"x12"x2" works well)
- Sand or Dirt to act as the asteroid's surface
- Tempera paint for the top coating of the asteroid (could alternatively use flour or glitter)
- Dry sieve or sifter

Helpful Hints

- Prepare multiple pans before the activity to save time.
- Be prepared to address the difference between real craters and these craters (such as how impactors breakup in Earth's atmosphere or how some crater structure is the effect of heat or shock). For example, impactors here don't disintegrate or break up, but remain in the crater.
- The equation for determining the final velocity of an impactor:

$$V=\sqrt{(2*g*d)}$$

Assuming no initial velocity and ignoring air resistance, where:

- *V* is the final velocity,
- *g* is the acceleration due to gravity (980 cm/sec^2), and
- *d* is the distance the impactor is dropped in centimeters

Procedure:

For setup ahead of time, lay out the pans willed with sand or dirt. For a more visible setup, feel free to show the application of the top layer of tempera, flour, or glitter.

1. Look at photos of the craters on the Moon, Mars, asteroids, other moons, and Earth.
2. Make a hypothesis: After looking at these photographs, how do you think the craters were formed? What do you think are factors that affect the appearance of craters and ejecta?
3. Preparing a "asteroid" test surface:
    a. Fill a pan with sand or dirt to a depth of about 2.5 cm (1 inch).
    b. Smooth the surface then tap the pan to make the materials settle evenly.
    c. Sprinkle a fine layer of dry tempera paint (or flour/glitter, whichever is available and will provide a color distinction) evenly and completely over the surface. Use a sieve or sifter for more uniform layering.
    d. What does this "asteroid" surface look like before testing?
4. Select impactors of different sizes and densities.
5. Use the balance to measure the mass of each impactor.
    a. Record the mass on the "Data Chart" for this impactor.
6. Follow the experiment:
    a. Drop impactor #1 from a height of 60 cm.. (2 ft.) onto the prepared surface.
    b. Measure the diameter and depth of the resulting crater.
    c. Note the presence of ejecta (rays). Count the rays, measure, and determine the average length of all the rays.
    d. Record measurements and any other observations you have about the appearance of the crater on the Data Chart.
7. Repeat steps 4a through 4e for impactor #1, increasing the drop heights to 200 cm (6½ ft.)
    a. Note that the higher the drop height, the faster the impactor hits the surface.
8. Next, repeat steps 3 and 4 for the other impactor.

Results

1. Is your hypothesis about what affects the appearance and size of craters supported by test data? Explain why or why not.

    a. What do the data reveal about the relationship between crater size and velocity of impactor?

    b. What do the data reveal about the relationship between ejecta (ray) length and velocity of impactor?

2. If the impactor were dropped from 6 meters (20 ft.), would the crater be larger or smaller?

    a. How much larger or smaller? Explain your answer.

    b. (Note: the velocity of the impactor would be 1,084 centimeters per second.)

    c. Based on the experimental data, describe the appearance of an impact crater.

3. The size of a crater made during an impact depends not only on the mass and velocity of the impactor, but also on the amount of kinetic energy possessed by the impacting object.

    a. Kinetic energy, energy in motion, is described as:

        - $\frac{1}{2}mv^2$, where m = mass and v = velocity.

        - During impact, the kinetic energy of an asteroid is transferred to the target surface, breaking up rock and moving the particles around. How does the kinetic energy of an impacting object relate to crater diameter?

4. Looking at the results in your Data Tables, which is the most important factor controlling the kinetic energy of a projectile, its diameter, its mass, or its velocity?

    a. Does this make sense?

    b. How do your results compare to the kinetic energy equation?

    c. Try plotting crater diameter vs. kinetic energy as Graph #3.

Data Chart

Drop Height = 60 cm (2 ft.), Velocity = 242 cm/s (5.5 mph)

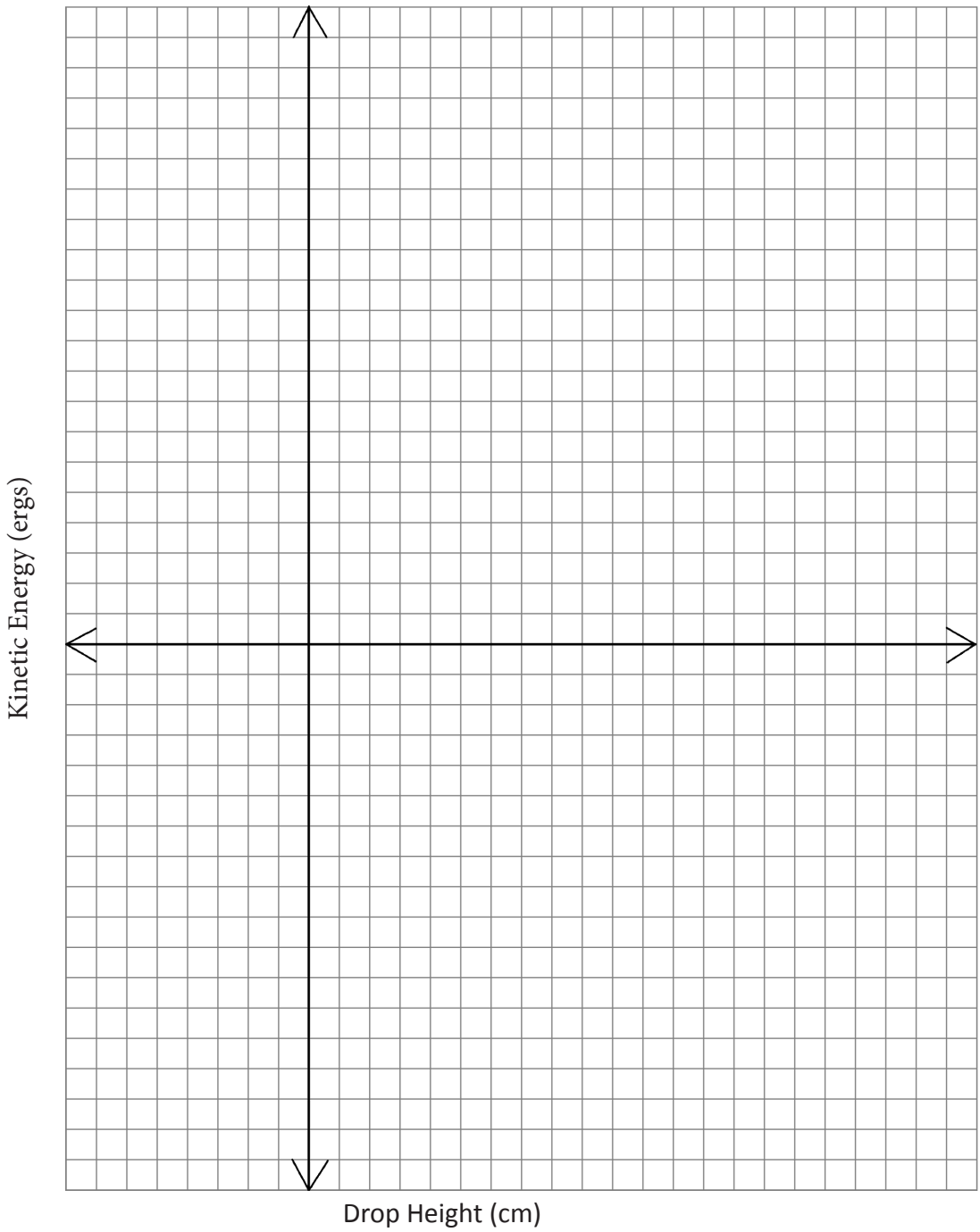
	Object 1 _____	Object 2 _____
	Mass _____	Mass _____
Crater Diameter		
Crater Depth		
Average Length of all Rays		
Kinetic Energy of Impact		

Drop Height = 200 cm (6ft.), Velocity = 626 cm/s (14 mph)

	Object 1 _____	Object 2 _____
	Mass _____	Mass _____
Crater Diameter		
Crater Depth		
Average Length of all Rays		
Kinetic Energy of Impact		

Graph Your Findings

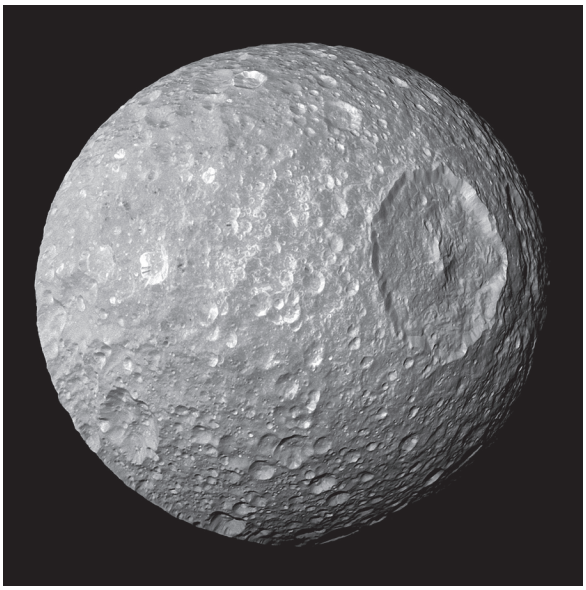
As you drop your impactors onto the asteroid's surface, calculate the amount of kinetic energy delivered in the impact. Once you have determined this amount, graph the kinetic energy delivered versus the height of the drop. Do this for both impactors you use. What do you notice about the graph?



Connection to the Next Generation Science Standards

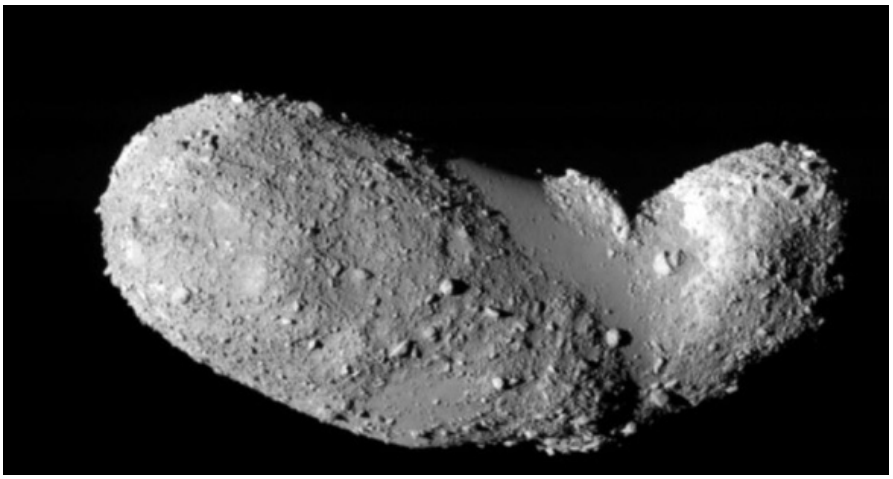
Intended Age Range			Middle and High School
Materials Sources			grocery store, superstore, or hardware store
Time to Complete Activity			45-60 minutes
Optimal Venue			Large Area
Assessment			graph paper, data sheet, class discussion
Next Generation Science Standards	**Elementary School**	4.E: Energy, a.	Construct a simple explanation for the relationship between energy and motion.
		6. SSS: Stars and the Solar System, b.	Provide evidence that Earth is spherical and the gravitational force of the Earth causes objects near the surface to be pulled toward the planet's center.
	Middle School	MS.ESS-EH: Earth History, c.	Construct explanations from evidence for how different geologic processes shape Earth's evolution over widely varying scales of space and time.
		MS.ESS-EH: Earth History, d.	Use empirical evidence from the rock and fossil records to investigate how past geologic events have caused major extinctions of life forms on Earth and how these extinctions have subsequently allowed other life forms to flourish.
		MS.PS-SPM: Structure and Properties of Matter, a.	Construct and use models to explain that atoms combine to form new substances of varying complexity in terms of the number of atoms and repeating subunits.
		MS.PS-CR: Chemical Reactions, b.	Generate and revise explanations from the comparison of the physical and chemical properties of reacting substances to the properties of new substances produced through chemical reactions to show that new properties have emerged.
		MS.PS-E: Energy, a.	Construct an explanation of the proportional relationship pattern between the kinetic energy of an object and its mass and speed.
		MS.PS-FM: Forces and Motion, b.	Communicate observations and information graphically and mathematically to represent how an object's relative position, velocity, and direction of motion are affected by forces acting on the object.
		MS.PS-FM: Forces and Motion, c.	Collect data to generate evidence supporting Newton's Third Law, which states that when two objects interact they exert equal and opposite forces on each other.
		MS.PS-IF: Interactions of Forces, b.	Use a model or various representations to describe the relationship among gravitational force, the mass of the interacting objects, and the distance between them.
	High School	HS.PS-FM: Forces and Motion, a.	Plan and carry out investigations to show that the algebraic formulation of Newton's second law of motion accurately predicts the relationship between the net force on macroscopic objects, their mass, and acceleration and the resulting change in motion.
		HS.PS-FM: Forces and Motion, b.	Generate and analyze data to support the claim that the total momentum of a closed system of objects before an interaction is the same as the total momentum of the system of objects after an interaction.
		HS.PS-FM: Forces and Motion, c.	Use algebraic equations to predict the velocities of objects after an interaction when the masses and velocities of objects before the interaction are known.
		HS.ESS-EH: Earth History, c.	Construct explanations about changes that occurred to Earth during the Hadean Eon based on data from Earth materials, planetary surfaces, and meteorites.

Crater Photos:



Saturn's moon Mimas taken by the Cassini spacecraft orbiting Saturn.
Image Credit: NASA

Asteroid Itokawa was imaged by the Hayabusa mission which returned microscopic grains from the surface of Itokawa.
Image Credit: JAXA



Asteroid Ida imaged by the Gallileo spacecraft en route to Jupiter
Image Credit: NASA

Asteroid Eros taken by the NEAR-Shoemaker spacecraft which visited Eros.
Image Credit: NASA

The astronauts aboard Apollo 10 took this image of Moltke crater on the moon.
Image Credit: NASA