Down to Earth
KS3

Teachers' Guide

Creating Craters

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Creating Craters!

Overview

This lesson allows pupils to create impact craters in layered dry materials. Pupils can perform controlled experiments by varying the velocity or mass of crater-forming objects and observing and measuring their effects.

Aims

- To give pupils an opportunity to make predictions, isolate and manipulate variables, and collect data in order to test their hypotheses.
- To encourage pupils to use graphs, tables and diagrams to present their data.
- To give pupils an understanding of the relationship between velocity, mass and kinetic energy, and the effects of these variables on crater formation.

Objectives

Pupils will:

- manipulate the variables of velocity and mass to investigate how these affect the formation of craters.
- identify various structures caused by the cratering process.
- recognise the conditions that control the size and appearance of impact craters.
- state the relationship between the size of the crater, size of the projectile, and velocity.
- demonstrate the transfer of energy in the cratering process.

Background

Impact craters are formed when objects such as meteorites, asteroids and comets strike the surface of a planetary body. Craters are found on all the terrestrial planets; Mercury, Venus, Earth and Mars; the Earth's Moon, and on most of the moons of other planets.

Geological clues and studies of the lunar rocks returned by the Apollo missions indicate that about 3.9 billion years ago asteroid-size chunks of matter were abundant in the solar system. This was a time of intense bombardment of the young planets, affecting Earth by breaking up and modifying parts of the crust.

Processes such as mountain building, plate tectonics, weathering and erosion have largely removed the traces of Earth's early cratering period. But the lack of weathering on the Moon has allowed the evidence of this ancient time to be preserved.

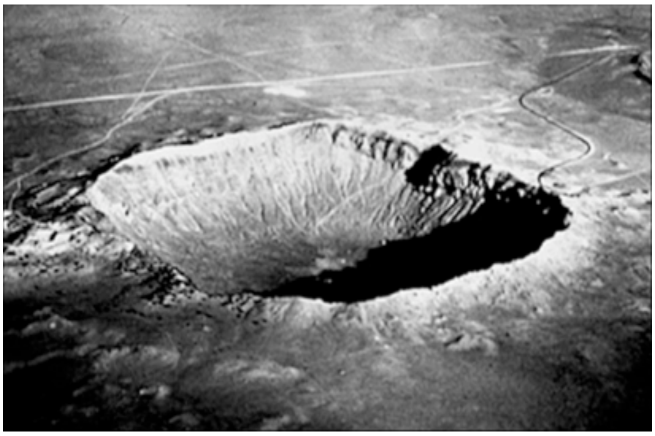
Impact Energy

Impact craters are formed by the transfer of energy from a moving mass (meteorite) to a stationary body (planet). Kinetic energy is the energy of motion.

It is defined as one half the mass of an object multiplied by the velocity of the object squared (K.E. = 1/2 Mv^2). Objects in space move very fast, so this can be a huge amount of energy!

In an impact the kinetic energy of a meteorite is changed into heat that melts rocks and energy that pulverises and excavates rock.

Simplified demonstrations of this transfer of energy can be made by creating impacts in powdered materials. If identical objects are impacted into powdered materials from different heights then pupils can determine the effect velocity has on the cratering process. Likewise if projectiles of different masses are impacted from the same height and the same velocity, pupils will be able to identify the relationship of mass to crater formation.



Barringer (or Meteor) Crater in Arizona was formed by the high velocity impact and explosion of an iron meteorite about 30 metres in diameter. The crater is over one kilometre wide. In the classroom the low velocities and low masses will make craters much closer in size to the impacting bodies.

Creating Craters

Overview

Pupils perform controlled cratering experiments in dry materials. They vary the impactor velocity or mass and observe and measure the effects.

Materials

- large tray or sturdy box 8-10 cm deep and about 1/2 m on each side (1 per group)
- sand (approx. 4 to 5 kg per tray)
- fine coloured sand or dry paint - enough for a thin layer to cover the surface (A dust mask should be used when sprinkling paint).
- projectiles (provide one set of either type for each group of pupils)

SET A - (provide enough sets for all groups) four marbles, ball bearings, or similar of identical size and weight

SET B - (provide one or two sets per class) three spheres of equal size but different materials so that they will have different mass (glass, plastic, rubber, steel, wood)

Rulers & metre sticks	Digital balance (one per class)
Data Chart (per group)	Pupil Procedure (one per group)

Advanced Preparation

1. Assemble equipment.
2. Prepare projectile sets and label.
3. Copy Pupil Procedure and Data Charts as needed.
4. Prepare target trays of sand and fine sand/paint.
   i. Place an even, 3 cm deep layer of sand in the bottom of each tray.
   ii. Sprinkle a thin layer of fine sand over the coarse sand.
   iii. Place another very thin (2-3 mm) even layer of paint on top of the fine sand.

Procedure

1. Pupils should work in small groups. Each group should choose at least three projectiles from SET A or SET B.

2. Write a description of each projectile on your Data Chart.

3. Measure the mass and dimensions of each projectile and record these on the Data Chart.

4. Drop the projectiles into the dry material.

SET A

i. Drop the projectiles from different heights (suggest 2-3 m).

ii. Record all height data and crater observations.

SET B

i. Drop all projectiles from the same height.

ii. Record data and crater observations.

5. Discuss the effects caused by altering the variables of height/ velocity and mass.

Creating Craters!

Equipment (Per Group)

- One set of projectiles either SET A or SET B

SET A: four marbles, ball bearings, or similar of identical size and weight

SET B: three spheres of equal size but different materials so that they have different mass

- Ruler and metre rule
- Digital balance
- Data Chart

Method

1. Choose at least three projectiles from SET A or SET B.
2. Write a description of each projectile on your Data Chart.
3. Measure the mass, and diameter across the longest side of each projectile and record these on the Data Chart.
4. Prepare dry material layers according to directions from your teacher.
5. Drop the projectiles into the dry material.

Depending on which projectiles you are using this will be different:

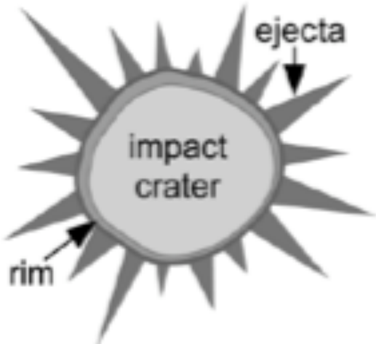
> **SET A**:
>
> Drop the projectiles from different heights. The projectiles should be dropped one at a time into an undisturbed area of the tray. Record each height selected and your crater observations (see Crater Features below).
>
> **SET B:**
>
> Drop all projectiles from the same height. The projectiles should be dropped one at a time into an undisturbed area of the tray. Record the height selected, the mass of each projectile, and your crater observations.

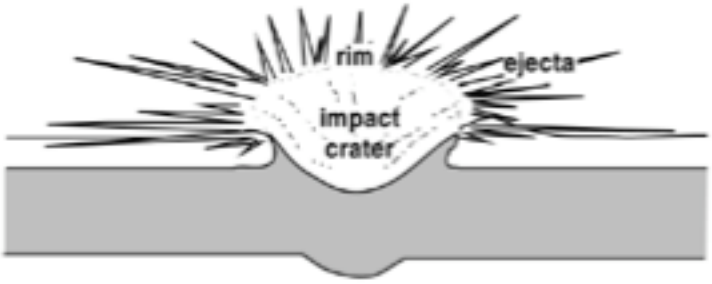
6. Discuss the effects caused by changing the variables of height (and so velocity) and mass of an object on the crater it forms.

Crater Features

The energy of an impact vaporises and displaces material creating the impact crater, a basin surrounded by the crater rim.

The ejected material falls back to Earth to form a carpet of ejecta and a pattern of rays.





This diagram shows two views of a typical impact crater.
the left view shows the circular cater with its rim and scattered ejecta. the right view shows that the rim is above and the crater floor is below the original surface. the ejecta are thickest closest to the rim.

Options:

- Using results from Set A- Plot ray length vs. height when the mass of the projectiles are equal. Measure ray length from the centre of a crater to the end of the longest ray for each crater.
- How would we expect the height from which each projectile is dropped to affect its velocity? Remember, the Set A projectiles are identical in size.
- Using results from Set B- Plot a graph of ray length vs. mass of projectiles when the height and size of the projectiles (and therefore their velocities) are equal.
- Experiment with different velocities by throwing projectiles into dry materials. You must first consider any safety concerns!

Questions

1. What evidence was there that the energy of the falling projectile was transferred to the ground?

2. How does the velocity of a projectile affect the cratering process?

3. How does the mass of a projectile affect the cratering process?

4. If the projectile exploded just above the surface, as often happens, what changes might you see in the craters?

Energy Calculations for Advanced Classes

The following formulae allow more able pupils to calculate the K.E. involved in each impact. This might allow the pupils to, for example, plot the kinetic energy of an impactor against crater diameter or ray length.

K.E.	=	kinetic energy
M	=	mass of impacting object (projectile)
g	=	gravity constant for Earth (980 cm/sec^2)
v	=	velocity of impacting object (projectile)
h	=	height of release of impacting object
erg	=	grams x cm^2 x sec (measure of K.E.)
K.E.	=	1/2 Mv^2 (meteorite impacts like Meteor Crater)
v	=	$\sqrt{2gh}$ (free fall)
K.E.	=	Mgh (for classroom experiments)

Classroom Experiment Example

projectile	-	10 grams	=	M
drop height	-	2 metres	=	h
gravity effect	-	980cm/sec^2	=	g

K.E. = 1/2 x 10 grams x 2 x 980 cm/ sec^2 x 200 cm

Meteor Crater Estimate

Projectile was 30 metres in diameter.

It was an iron nickel sphere (a meteorite with a density of 8 g/cm^3)

Projectile mass was 1.1 x 1011 grams = M

4/3 Π (1.5 x 103) 3 cm^3 = v

(1.4 x 1010 cm^3) = v

K.E. = 1/2 x 1.1 x 1011 grams x (2 x 106)^2

K.E. = ~ 2 x 1023 ergs