

AS101 Lab: Impact Craters

Name:

Pre-lab

Pre-lab check:

A ball with a mass of 0.5 kilograms will be released from rest at a height of 11.25 meters. It hits the ground with a velocity of 15 m/s. Assume a value of 10 m/s/s for g .

1. What is the total energy (potential+kinetic) of the 0.5 kg ball before it is released from rest at a height of 11.25 m?
2. What is the total energy (potential+kinetic) of the 0.5 kg ball right before it hits the ground?
3. What is the total energy of the ball at any time during its fall?

AS 101 – Planet Topography – Impact Craters

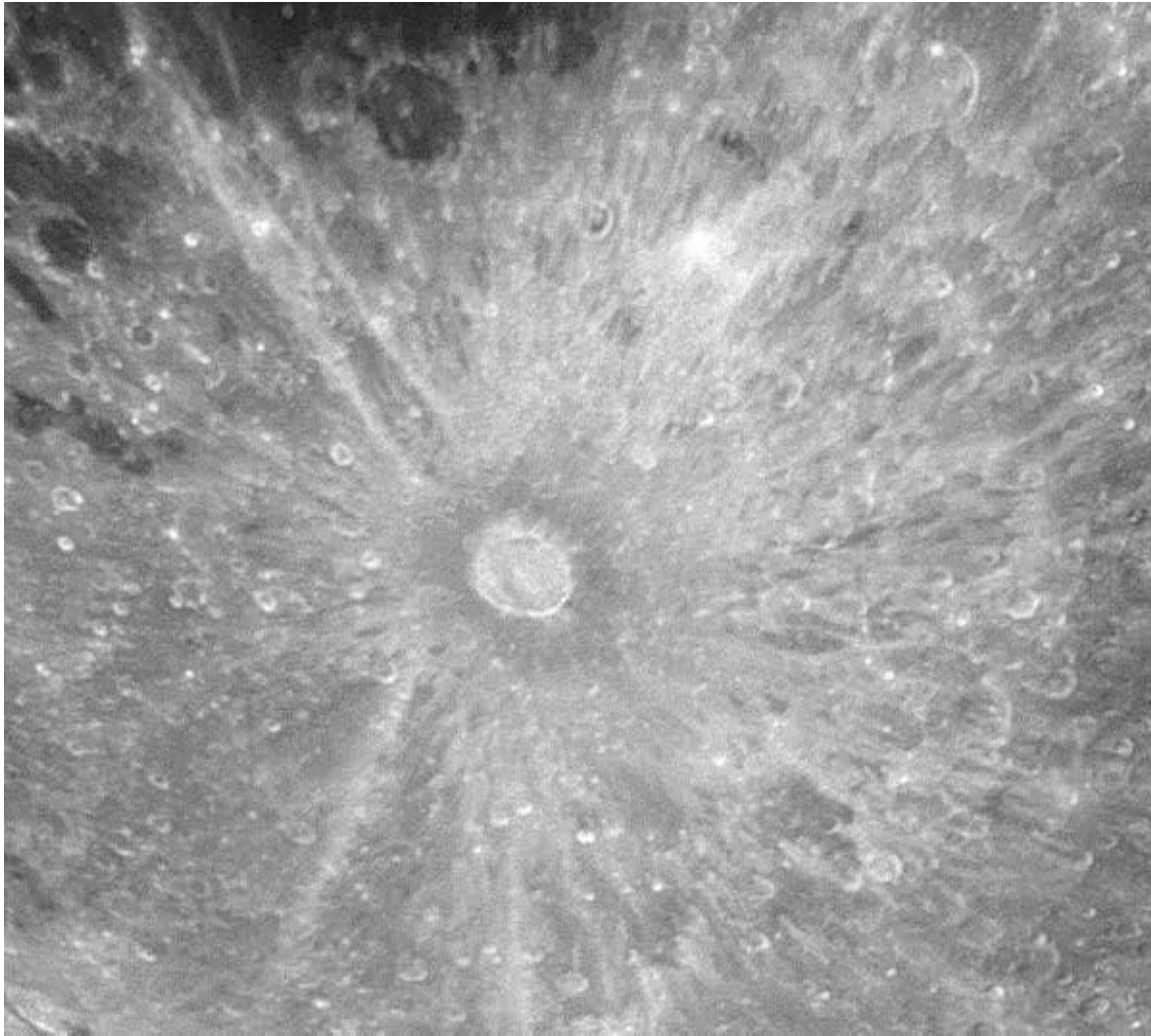


Figure 1– The lunar crater Tycho is a young impact crater (about 100 million years old), with a diameter of 85 km. It is the youngest large crater on the Moon. At the time of full moon an extensive series of rays is easily visible in a small telescope.

The Problem:

Impact craters are ubiquitous throughout the solar system – but how are they made? What is the distribution of their sizes, and how do their numbers change from place to place? What determines the size and shape of a crater? The focus of this exercise will be to understand how craters are produced; what the relationship is between the size and energy of the impacting body and the resulting crater and what the numbers of craters on a planetary surface tells us about the surface. The hypothesis is the impact theory – that as the name suggests, impact craters are produced when high-speed objects strike the surface of a planet. **Meteoroids** are small rocky or metallic body in outer space (significantly smaller than an asteroid). A meteoroid that survives its passage through a planetary atmosphere and impacts the ground is termed a **meteorite**. Craters are formed by meteorites.

Introduction:

One of the best ways to learn how the surfaces of planets got to their present state is to compare one planet with another. How have the surfaces of planets been modified – was it through impact cratering, volcanism, weathering or tectonic activity? On the Earth, we can find examples of all of these processes; the surface of the Earth has been and continues to be modified (sometimes dramatically and catastrophically) by all of these processes. But the most ubiquitous features on planetary surfaces are impact craters. The primary goal of this exercise is to test the hypothesis that impacts do produce craters with the right sort of properties to explain what we see throughout the Solar System.

The idea of impact cratering is a simple one; any small body that impacts a surface has to dissipate its kinetic energy virtually instantaneously. The kinetic energy is dissipated either by heating both the incoming body and the surrounding surface, or at lower energies (such as you will have in the lab) the energy will be dissipated as random motions of the surface material – that is stuff will be knocked out in all directions by the impact, leaving a crater with a characteristic profile and circular shape.

The goals of this exercise will be to make several tests of the impact crater hypothesis.

1. Does the size of a crater depend on the kinetic energy of the impacting object alone, or does the diameter of the object play a role as well?
2. Do craters have circular shapes, regardless of the angle at which the impacting body approaches?
3. Explore the surfaces of various planetary bodies in the Solar System and date the relative ages of their surfaces by counting the numbers of craters.
4. What is the size distribution of impact craters? How does this relate to the size distribution of impacting objects in the solar system?

Available equipment:

1. Impact Equipment: steel balls, buckets of fine glass bead material, digital scale, iron filings, small ruler, meter stick.
2. Images and maps of planetary bodies.
3. Plaster “meteorite”.

Part I: Impact Experiment

You will need to devise an experiment to test the mechanism behind cratering with respect to two variables: the kinetic energy of the impacting body and the diameter of the impacting body. **We want to know if the size of a crater is dependent solely upon the kinetic energy of the impacting body, or if the diameter of the object plays a role as well.**

Definitions:

Energy:

Energy is measured in units of Joules. It comes in many different forms, but we will deal with mechanical energy. There are two types of mechanical energy: kinetic and potential.

If a mass m moves with a velocity v it has kinetic energy:

$$T(v) = \frac{1}{2}mv^2$$

A mass dropped from a distance h above the surface of the Earth will have some final velocity v_f when it hits the surface, it will have a corresponding kinetic energy $T(v_f)$ as well. Thus, if the mass is held stationary at the height h above the surface, you could say it has the potential to achieve a kinetic energy $T(v_f)$ if you drop it. When the mass is held at height h it has a Potential energy:

$$U(h) = mgh$$

Where g is the gravitational acceleration 9.8 m/s^2 .

Thus if you drop a mass m from a height h above the sand, it will have a kinetic energy equal to mgh when it lands. All of its potential energy becomes kinetic energy.

$$T(v) = U(h) = mgh$$

Energy:

1. Choose 2 metal balls of different diameter to drop.
2. Measure the mass and diameter of each, *record on the worksheet on the following page.*
3. Ball 1 and ball 2 can be dropped from different heights such that they will have the same kinetic energy when they land. Pick energies such that your heights do not go above 2 meters.
4. For each energy, drop the balls from their respective heights and measure the diameter of the craters. Do 3 drops per ball.
5. Repeat for a second energy

Mass of Ball 1:

Mass of Ball 2:

Experiment	Energy	Height for Ball 1	Height for Ball 2	Size of Crater from Ball 1	Size of Crater from Ball 2
1				Trial 1:	Trial 1:
				Trial 2:	Trial 2:
				Trial 3:	Trial 3:
				Average:	Average:
2				Trial 1:	Trial 1:
				Trial 2:	Trial 2:
				Trial 3:	Trial 3:
				Average:	Average:

Shape:

1. Sprinkle iron filings on the surface of the sand.
2. Drop one ball from straight above. Sketch the shape of the crater and the ejecta blanket.
3. Resurface with iron filings
4. Roll a ball off of the lab table into the bucket such that it impacts at an angle. This is called an oblique impact. Sketch the shape of the crater and the ejecta blanket.

Direct impact

Oblique impact

Questions:

- 1) Show how you calculated the height of the second ball.
- 2) How can we determine the kinetic energy from the potential energy at any height? (Write an equation for kinetic energy, T , for a ball that was dropped at height, h_0 , of mass, m , at any height, h .)
- 3) Compare the average crater size of two balls at the same potential energy. What does this tell you about the roles of mass and energy in forming craters?

- 4) Compare the average crater size of the same ball at different potential energies. What does this tell you about the roles of mass and energy in forming craters?

- 5) Describe in words the differences in crater shape between a direct impact and an oblique impact.

- 6) Think about images of cratered celestial bodies (moons, planets), using what you've learned from this experiment, what do you think causes the diversity of crater sizes and shapes?

Part II: Planetary Surfaces

- The class will determine the crater number density of several planetary surfaces.
 - These densities will be used to rank the surfaces by age. The number density is proportional to the age of the surface.
 - The class will also determine the size distribution of craters on the planetary surfaces
1. What two planetary surfaces are you looking at?

 2. What is the area of each region (using the scale in the book) that you are looking at?

3. How many craters did you find:

	Small	Medium	Large	Total
Planet 1				
Planet 2				

4. What is the total Crater density for each planetary surface? (Density=number of craters/area)

5. Compare the two values, what does this tell you about each planet?

6. Make histograms for craters of number vs. size, one for each planet. This can be done by hand or in excel. Compare in words the shape of these histograms.

Part III: Meteorite Size Distribution

- A plaster “meteoroid” will be destroyed to simulate the breakup of cosmic debris in the solar system. The size distribution of the fragments will show a possible explanation for the distribution seen during Part II.

1. How many meteoroids did you find: Don’t record anything under 3mm.

	Small	Medium	Large
Meteoroids			

2. What were your size criterion?

3. Create a histogram of this data.

4. What can you infer about the size distribution of real meteorites from the data obtained from this experiment?

5. How do the histograms from part II and part III compare to one another? What conclusions can you draw from their similarities or differences?