TA Guide for

ASTR 310 Tutorial: Craters

ver. 101112

Notes

Description

In this activity, students drop different kinds of ball bearing into a bucket of sand. The ball bearing forms a beautiful little crater. It may seem kind of random, but through a controlled experiment the students will discover there is a relationship between the size of the ball bearing (the "impactor") and the diameter of the crater. With an idea about *how* craters form, the student turn to a "surface chronology" exercise of reconstructing the formation and evolution of the surface of a planet by interpreting the presence (or absence) of craters. This is just one example of something they see in class – deducing the formation and evolution of the Solar System by looking at patterns.

Learning Goals

After all the lectures and this tutorial, the student should be able to

- predict the size of the crater formed by a given impactor (The students discover a nearly-linear relationship between impactor diameter and crater diameter)
- observe that the crater is many times larger than the impactor. (In this activity, they will uncover a factor of about 4.)
- reconstruct the formation and evolution of the surface of a planet by interpreting the presence or absence of craters ("surface chronolgy")

The goal for the activity is to let the students discover as much as possible by themselves. The students will also have the opportunity to make a prediction and then test it. In other words, this is not a "recipe" activity ("Do this. Now do this. Now this.")

Preparation

Each group of 2-3 students needs:

- container with sand
- set of ball bearings **with 12.7 mm steel ball bearing removed**: 5 steel ball bearings, 1 each of brass, nylon, teflon. You'll give the students the 12.7-mm ball bearing during the tutorial (so be sure to remove it from the container before the next tutorial section.)
- metre stick
- small, flexible flashlight
- transparency with crater size gauge
- transparency with ball bearing size gauge

Other items needed for activity:

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- 1 copy of Pages 1–3, all single-sided, for each group
- 1 copy of Page 4 (Questions) for each student
- "Factors and characteristics" overhead
- 8 overheads of real craters: Moon, Mars, *Opportunity*, Endeavour, Mercury, Mimas, Death Star, Earth
- all the 12.7-mm ball bearings removed from the containers

Set out the equipment before the tutorial starts, to maximize the amount of time the students have to experiment. Put the container of sand on the floor, not the desk: sand + computers = Wrath of Gerry. We've found that if the students have the worksheets, they dive right into the activity and don't play with the ball bearings. We want them to play and explore, so it's better *not* to set out the worksheets. Instead, hand them out when they're needed.

Part 1: What should we measure?	10 min

As soon as the students start gathering in the room, put them into groups of 2–3 and get them to "play" with the craters. Ask them to make as many different kinds of craters as possible, doing whatever they want with the ball bearings. Ask them, if necessary, to keep the container of sand on the floor.

After everyone has had a chance to play with the craters (for, say, 5 minutes), direct their attention to the front of the room and let them know why we're interested in craters:

> We find craters on planets and moons all over the Solar System:

Crater overheads

> 1. Moon: notice how many craters there are, of all different sizes, and that some surfaces are smooth while others are totally destroyed...
> 2. Mars: this is Victoria Crater that the Mars rover *Opportunity* explored. It's 730 metres across.
> 3. This is *Opportunity*
> 4. This is where it's going – Endeavour Crater
> 5. Mercury: recent picture from MESSENGER spacecraft
> 6. Saturn's moon, Mimas
> 7. the Death Star *Ha! Ha!*
> 8. Finally, yes, Earth gets hit, too. Here's the Barringer Crater in Arizona, 1200 metres across. (notice the tiny road leading to the crater)
>
> These craters have different sizes and shapes. Each one forms when meteor or asteroid or piece of debris - **let's just call it an impactor** - hits the surface. We'd like to understand how they form, because that will tell us about how the Solar System formed.

While TA-A is going over this, TA-B can hand-out Page 1 Put up the "factors/characteristics" overhead.

Hand out
Page 1
factors overhead

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> You've all been playing with craters. What factors matter? What factors determine the shape of a crater?

Give them a minute to write down what they found. Then brainstorm, waiting until later to evaluate their suggestions. Write the responses on the overhead. You should get things like size, mass, material, speed, drop height, angle of impact. If it doesn't come up, prompt them to think about craters in the Solar System, not just the ones in the lab:

> What about craters in the Solar System? Are there any differences between craters on the Moon and craters on Earth?

Hopefully students will suggest gravity, maybe also "hardness" of the surface, whether or not the planet has an atmosphere.

> The appearance of a crater depends on many things, too many for us to explore here in this room, on Earth. So you are going to do a more controlled experiment where only a few factors change.

Go down the "appearance" list on the overhead and highlight the factors we'll explore and those we'll ignore or keep constant. For example, it might look like this:

The appearance of a crater depends on these factors:
mass – we'll change the mass of the ball bearings
speed – drop the balls from 1 metre
distance/height – drop from 1 metre
angle – we'll drop the ball bearings straight down
composition – we'll use only the steel ball bearings
shape – the ball bearings are round
rotation - don't worry about it
size – related to mass

> We are going to investigate how craters form so we need to be able to tell one crater from another. What kinds of things can you measure about a crater?

Write their responses on the overhead: size, depth, shape, rim, central peak, etc. Then browse over the "Characteristics" list, perhaps mention how some characteristics are related (for example, diameter and circumference) but inform the students they'll be using **diameter** to characterize each crater.

Part 2: Explore, Discover and Predict — 15 min

Outline the controlled experiment they're going to perform:

Hand out Page 2

> Now you're going to investigate the relationship between the size of the impactor and the size of the crater. Remember to use only the steel ball bearing dropped

from a height of 1 metre. Measure the diameter of the crater using the overhead "gauge" and record all your results in the Table. It really helps to see the size of the crater if you shine the flashlight along the surface of the sand.

Drop each ball bearing a couple of times.

When you've collected enough data, draw a couple of graphs. The goal is to make the graphs good enough that you can predict the size of the crater that will form when you drop a certain ball bearing from 1 metre.

It doesn't matter what kind of graph it is, as long as they can use it to make a prediction about the crater formed by a 12.7-mm (8.4-g) ball bearing. After they show you their prediction, give them the 12.7-mm ball bearing and get to test their prediction. This is, potentially, a "golden moment" – some students are genuinely excited to do this experiment and test their prediction. It could be one of the only times they've ever "done" something scientific.

As you walk around, try to ask each group if the test worked. Did the crater match their prediction? If it did, let them know they just told the future! And if it didn't, ask them why not? Bad graph? Bad drop? Bad measurement? Did the ball bearing land too close to the side of the container?

Part 3: Surface Chronology — 5–10 min

It's possible the student haven't yet heard in class that surfaces "accumulate" craters or about a surface's "accumulation age". As students get to this Part, remind them to carefully read the introduction.

Hand out Page 3 as needed

This activity is quite simple to do, though it takes a bit of thinking and logic to figure out the later questions. The first part is to arrange the 4 regions **qualitatively** from oldest to youngest - simply which one has the most craters to which has the least.

The second part is to arrange the regions **quantitatively**. The students are told that impacts occur at a rate of 14 per billion years. To estimate the ages of the regions, they count the number of craters and divide by 14.

Part 4: Questions — Remainder of tutorial

When the students have completed the surface chronology activity, give each student a question sheet to answer:

Hand out Questions as needed

1. The students should find the ratio (crater diameter)/(impactor diameter) is constant. If they're having trouble deciding what happens when they drop the ball bearing from a greater height, get them to go back to their container and try it...

2. Both the graph in Part 2 and the Table in Question 1 are evidence that, with all other variables constant, the diameter of a crater is directly proportional to the diameter of the impactor. So, rock *b* should make a crater 2 times wider than rock *a*. But if they're stuck, get them to experiment with 2 ball bearings, like the 12.7 mm and 25.4 mm ball bearings.

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3. Remind the students they are looking for an **interval** of time, not just one time, to indicate when the craters formed in Region C.

4. This question tests the “logic” behind what makes a region “young” or “old”. The first choice is the answer: region *a* is younger because it’s been more recently smoothed over by a flood or volcano so that fewer craters have accumulated.

Clean up

Make sure the ball bearing sets are complete: **six** steel ball bearings (that is, put the “missing” ball bearing back in case ASTR 101 needs it), 1 brass ball bearing and 2 white plastic ball bearings.

Also, check that all the flashlights are switched off so the batteries last longer.