



# IMPACT CRATERS

*Purpose:* The purpose of this lab is to understand how impact craters form and how this formation depends upon the nature of the impactor and the impacted object. The concept of modeling events at different physical scales is also explored.

**Setup:** Form groups of no more than 4 students. Try to ensure that each group has a member that has completed an astronomy class that focused on the Solar System. (At ECC, this class is Astro 9 or Astro 20, depending on when taken.) This person will serve as your “resident expert”. Most scientific collaborations include one or more people that are more familiar with the field of study than the rest of the group, so your group should reflect that fact. The expert won’t know everything, but they should be of some assistance at times.

Obtain a crater test box and supplies. The supplies should include:

- the crater box which contains a lot of flour,
- a 2-inch diameter plastic tube,
- a small (wood) retainer “plate” to hold over the end of the tube,
- a ruler, and
- a spoon.

You should also know the whereabouts of:

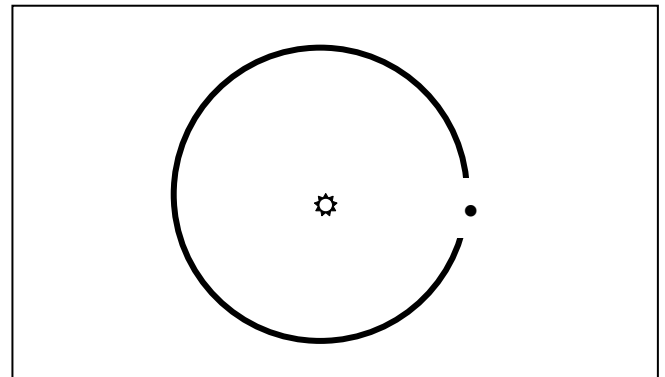
- a flour sifter,
- a smaller diameter plastic tube, and
- coloring compounds for coloring **small** amounts of the flour.
- scratch paper

## Part I – Cratering Concepts.

Answer the following questions on a separate sheet of paper.

### *Questions*

1. [1/2 pt] Define what an impact crater is (work as a group). Write your best definition.
2. [1/2 pt] Compute the orbital speed of the Earth, using the fact that the Earth completes one orbit around the Sun in a year. There are 31 million seconds in a year, and 1 AU = 150 million km = 93 million miles. Show work.
3. [1/2 pt] Where do the objects that cause impact craters come from?
4. [1 pt] The diagram below shows the Sun and the Earth in its orbit. Work as a team to develop what you think is a good example of the trajectory of an impactor leading up to a collision with Earth. Sketch a portion of its orbit prior to hitting Earth on your answer sheet.
5. [1/2 pt] Escape velocity measures how fast an object must go to be able to leave an object behind (and not fall back towards it). Given the answer to question 2, and the fact that the escape velocity equals  $\sqrt{2} = 1.414$  times the orbital velocity, calculate the escape velocity required for an



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object in orbit around the Sun, at the Earth's distance. This is how fast it would need to go to leave the Solar System.

6. [1 pt] Why is it unlikely that an object would be traveling much faster than this escape speed when it impacts Earth?
7. [1 pt] Using the answer to questions 5 and 2, estimate the *maximum* impact velocity for an object on Earth.
8. [1 pt] What would be a reasonable *minimum* impact velocity? (**Hint:** note that to leave the Earth's surface behind, an object obtain a speed of 11 km/sec. Because gravity is symmetric, this is also the velocity an object will have if it starts at rest from far away and is gravitationally pulled to Earth.)
9. [1/2 pt] The speed of sound (mach 1) is approximately 300 m/sec. The fastest jets can travel up to about 3 times faster than sound (mach 3), which is faster than even most high-power rifle bullets (Mach 1-2). What Mach number do impactors have when they hit earth?
10. [1.5 pts] List all of the things that determine the size of an impact crater when an object hits the Moon. In your list, indicate which properties of the object are related to which other properties. (Unrelated example: paper's color and brightness would be related – white things are brighter than black things because white things reflect light and black things absorb it.) Rank the properties from most to least important. Up to 2 points of **Extra Credit** will be awarded based on the correctness of the rankings.
11. [1 pt] In order to model impact craters in the lab, we obviously need to slow things down a bit! If we do that, what other changes must we make in order to produce realistic craters? List at least 2 changes.

### **Part II Crater Sizes and Ejecta Ranges vs. Impact Parameters**

**Step 1:** Learn how to make an impact crater using your crater kit. Place three spoons of flour in the plastic tube and drop the flour out of the tube from a height of 1m-1.5m. One person should make the impactor, another should prepare the surface, another person should be the dropper, and the last person should record the results. All team members should be judges. Experiment to find the best consistency for the surface and the impactor. Perform at least 3 trials per combination listed below, and always use the same amount of flour and the same drop height:

[2 pts] For each of the four combinations of surface and impactor, rate each of the 3 trial craters using the criteria below. Use a scale from 1-10, with 10 being the best crater. Feel free to add your own criteria. For each rating, give a brief justification for the rating (e.g. few rays, shallow crater, no rim, etc.)

**Criteria:** number of rays, rays' appearances, size of rim, quality of rim, depth of crater, overall structure of crater.

Surface/Impactor mixture:

- Compact surface and compact impactor
- Compact surface and loose impactor
- Loose surface and compact impactor
- Loose surface and loose impactor

**Step 2:** Compare the best crater that you can make with craters found on other worlds (use your textbook or one provided by your instructor).

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### *Questions*

12. [1.5 pts] Make notes on the similarities and differences between your best crater and the real craters. Also note what the environment is like on the worlds of the real craters. Other worlds: Moon/Mercury, Venus, Earth, Mars, Callisto
13. [1 pt] Explain some of the similarities and differences

**Step 3:** Using the best impactor/surface combination from step 1, measure crater diameter, depth, number of prominent rays, and the range of the ejecta as a function of drop height, impactor mass, and impactor diameter. Fill out the table on page 5.

### **Part III: Data Analysis**

**Step 1:** Graph your data. Make the following four graphs (one set per group):

- I) Graph crater diameter vs. drop height for the first four tests. (Drop height should be on the horizontal axis.) Try to estimate and connect the four points in your graph with a smooth curve that best fits the data. (Do not connect the dots – try to establish a pattern.) Now, add the results of your fifth and six tests to your plot using different symbols. Do not include these last two points in your smooth curve.

### *Questions*

14. [1.5 pts] Answer the following questions.
- What did you expect the curve to look like?
  - Is your curve what you expected?
  - Do the last two test points fit the curve?
  - Provide a theory to explain your results.
- II) Make a graph for crater diameter vs. impactor energy (horizontal axis).  
Same four questions as above
- III) Repeat for crater volume vs. impactor energy (horizontal axis).  
Questions  
Same four questions as above
- IV) Repeat for ejecta range vs. impactor energy.  
Questions  
Same four questions as above

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**Step 2:** Answer the following questions:

15. For real craters, with the velocities so high,
- [1/2 pt] what do you think happens to the impactor object when it hits? (Hint: think of the gigantic energy involved, and how quickly it must be absorbed by the surface and the impactor.)
  - [1/2 pt] In your experiment, what happened to the impactor?
  - [1/2 pt] How well did your experiments model the impactor's behavior after the collision?
16. Real impact craters typically are 10-times larger **in diameter** than the object that struck the surface.
- [1/2 pt] Is this what you found with your experiment?
  - [1 pt] Why the difference?
  - [1/2 pt] How much bigger in volume is a real crater compared to its impactor? (Remember the volume of a sphere =  $\pi/6 \times \text{Diam}^3 = 4\pi/3 \times \text{Radius}^3$ )
17. Answer the following questions.
- [1/2 pt] What happened with your angle-shot crater?
  - [1/2 pt] After it was formed, could you tell that the impactor hit at an angle? Why or why not?
  - [1 pt] In real impact craters, even ones striking almost horizontally, angle shots still produce round craters. Why do you think that this is so? (Hint: go back to your result for question 15).

### What to submit

- Answers to the questions above, including 4 instances of question 14 and a drawing for question 4.
- The table below.
- A table and/or notes judging crater quality and quantifiable properties, when determining which surface and impactor materials to use (e.g. loose flour vs. compacted flour). See Step 1, part II.
- Four graphs, all associated with question 14.

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Table 1 – Cratering data

Impactor Diameter	Spoons (# Sp)	Drop Ht.	Impactor Energy ~ #Sp x Ht.	Crater Diam	Crater Depth	Crater Volume V ~ Diam <sup>2</sup> xDepth	# Rays	Maximum Range of Ejecta
<b>2-inches</b>	<b>3</b>	<b>0.5 m</b>						
<b>2-inches</b>	<b>3</b>	<b>1.0 m</b>						
<b>2-inches</b>	<b>3</b>	<b>1.5 m</b>						
<b>2-inches</b>	<b>3</b>	<b>2.0 m</b>						
<b>2-inches</b>	<b>1.5</b>	<b>1.5 m</b>						
<b>1.5-inch</b>	<b>1.5</b>	<b>1.5 m</b>						
<b>2-inches</b>	<b>3</b>	<b>Angle</b>						