Lab 3: Impact Craters

Section	Points
Concepts/Objective 5	
Variables/Hypothesis 5	
Observations/Data 5	
Procedure 5	
Questions/Conclusion 10	
Total	
Regents Minutes	

Project Director	
Safety Director	
Materials Manager	
Technical Manager	
LabQuest #	
Laptop #	

Introduction/Pre-Lab

Every body in the solar system has been subjected to the impact of objects such as comets, asteroids, or accretionary debris. The Moon, Mars, and Mercury all have heavily cratered surfaces that are the result of tens of thousands of impacts. Most satellites in the outer solar system also display thousands of impact craters. These heavily cratered surfaces record the period of an intense, solar-system-wide bombardment that ended about 3.8 billion years ago. All traces of this period have been erased from the surfaces of the Earth and Venus because these two planets have undergone relatively recent activity, including tectonic, volcanic, and erosional activity. Since this period of intense bombardment, the impact rate has been about 100 times less. However, during the past 500 million years there have been several very large impacts on Earth that have affected the entire planet.

Today, impacts from comets and asteroids still occur on all bodies in the solar system, including Earth. Meteor Crater (1.2 kilometers diameter, 183 meters deep, with a rim height of 30–60 meters) in northern Arizona was created by the impact of a 25-meter-diameter iron asteroid approximately 49,000 years ago. In 1908 a small asteroid exploded in the atmosphere over an unpopulated region of Tunguska in Siberia, creating an atmospheric shock wave so strong that it devastated a 10-km^2 area. In July 1994, about 20 fragments of Comet Shoemaker-Levy 9 impacted the atmosphere of Jupiter and created atmospheric disturbances larger than Earth.

When a high-speed object strikes a surface, it produces an enormous amount of energy. This is called **kinetic energy** because it is caused by motion. The amount of energy produced in this way depends on the mass of the impacting object and the velocity with which it strikes the surface:

$$KE = \frac{1}{2}mv^2$$

where m is the mass of the object and v is its impact velocity. Asteroids hitting Earth have impact velocities from about 11 to 25 kilometers per second (about 25,000 to 56,000 miles per hour). Very large amounts of energy are released by impacts because the amount of energy released is proportional to the square of the velocity. For instance, an iron meteorite 1 kilometer in diameter hitting the surface at a velocity of 15 kilometers per second will release more than 4×10^{27} ergs of energy, the equivalent of about 100,000 one-megaton hydrogen bombs. The crater formed by such an event would measure about 10 kilometers in diameter. In an impact event the motion of the projectile (meteorite or comet) rapidly transfers kinetic energy to the planetary crust. Most of this energy takes the form of shock or pressure waves that travel at supersonic speeds through both the surface and projectile.

The size of an impact crater depends not only on the amount of energy released by the impact, but also on the gravity field of the planet or satellite, and certain properties of the projectile and surface rocks. For a given size impact, a larger crater will form on a planet with a weaker gravity field because it is easier to excavate the material. In all cases, a crater is many times larger than the projectile that formed it. Although the diameter of a crater depends on the complex interaction of many factors, a rough approximation is that the excavation crater will be about 10 times larger than the projectile that formed it. The depth of a crater is considerably less than the diameter. For example, simple craters on the Moon have a depth/diameter ratio from 0.14 to 0.2, i.e., the diameter is about 5 to 7 times greater than the depth. For complex craters on the Moon (larger than 20 kilometers in diameter), the depth/diameter ratio ranges from 0.1 to 0.05, i.e., the diameter is from 10 to 20 times larger than the depth. This is because slumping of the inner walls and formation of the central peak causes a shallower depth. Examples of crater formation and crater features are shown below. (Figure 1)

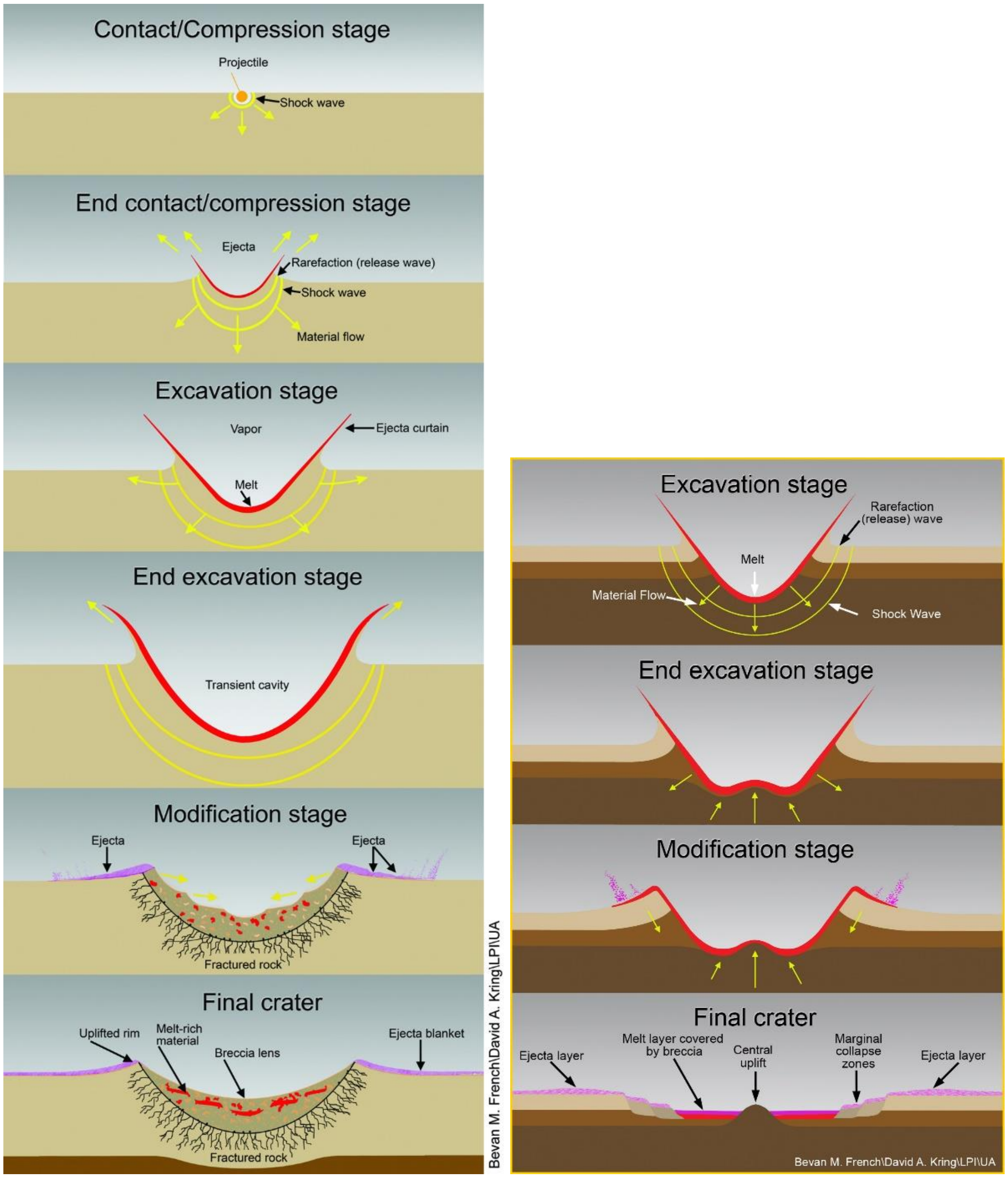

Figure 1: Simple and complex crater formation

Procedure

1. Turn on the labquest 2.
2. Connect the motion detector to the DIG/SONIC 1 input on the labquest 2.
3. Set the following parameters
   a. Mode: Time-based
   b. Rate: 20 samples/s
   c. Duration: 5 s
4. Hold the first object just blow the motion detector.
5. Press the "play" button on the bottom left of the screen and drop the object.
6. Using the graph on your LabQuest, determine the highest velocity reached by the object. (Note; this velocity should be just before ground impact)
7. Enter the velocities and mass into the table below.
8. Calculate the Kinetic energy of each object dropped using the formula KE = $\frac{1}{2}mv^2$

	Velocity 1	Velocity 2	Velocity 3	Average Velocity (m/s)	Mass (g)	Kinetic Energy
Object 1, Height 1						
Object 1, Height 2						
Object 2, Height 1						
Object 2, Height 2						

1. Looking at the results in your data table, what seems to be the most important factor controlling the kinetic energy of a projectile, its mass, or velocity?

2. Why do you think this is so? (Hint: Look closely at the formula for Kinetic energy)

3. How does the velocity of the falling objects compare when dropped from the same height? What do you think created these results?

SCIENCE CONCEPTS *(5 points)*

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Investigative question

If we drop a golf ball and a ping pong ball from heights of 0.5 and 1.5 meters, which variable will cause the most surface damage, height dropped or mass of impactor?

OBJECTIVE

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VARIABLES *(5 points)*

Manipulated Variable (Independent):____

Responding (Dependent):____

HYPOTHESIS (If…then…because)

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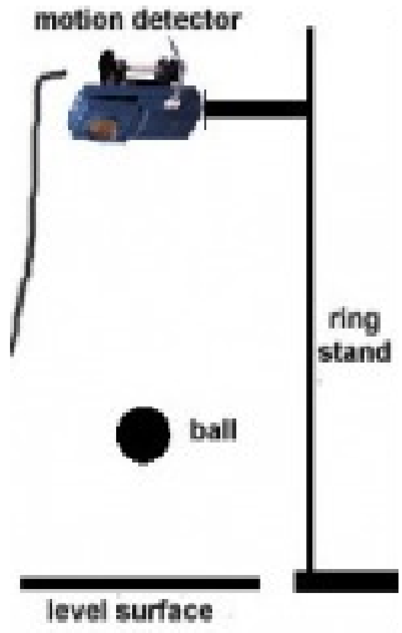
Materials

1. Golf ball
2. Ping-pong ball
3. Pan
4. Large construction paper
5. Flour
6. Colored Sand
7. Meter stick
8. Labquest 2
9. Motion detector
10. Ruler
11. Lab stand
12. Mass balance

Procedure

Part I

1. Set up experiment as shown in figure 2 using the labquest 2 and motion detector.
2. Turn on the labquest 2.
3. Connect the motion detector to the DIG/SONIC 1 input on the labquest 2.
4. Set the following parameters
    a. Mode: Time-based
    b. Rate: 20 samples/s
    c. Duration: 5 s
5. Fill your pan with flour to a depth of 2.5cm.
6. Smooth the surface by gentle shaking the pan back and forth.



7. Sprinkle the surface with colored sand.
8. Set the motion detector to the first height of 0.5 m above the top of the flour/sand.
9. Hold the first object just blow the motion detector.
10. Press the “play” button on the bottom left of the screen and drop the object.
11. Press the image of the “file cabinet” to move to the next run.
12. Record crater dimensions in the tables.
13. Repeat steps 6 through 11 for a total of 3 trials with the first object.
14. Repeat steps 6 through 12 for the next object at the same height.
15. Repeat steps 6 through 13 for the next height.
16. Save your data using the format (Name of Project Director, Lab #3, Period)
17. Record additional data in the Observations/Data Section
18. Determine which factor has the largest impact on crater size

DIAGRAM OF THE EXPERIMENT (based on the procedure) ***(5 points)***

OBSERVATIONS/DATA *(5 points)*

Part I:

TABLE__:____

Object 1:______________ Mass of Object 1:______________ Height 1:______________

	Trial 1	Trial 2	Trial 3	Total	Average
Crater Diameter (cm)					
Crater Depth (cm)					
Diameter/Depth					
Maximum length of ejected material (cm)					
Maximum velocity of Object (m/s)					

Object 2:______________ Mass of Object 2:______________ Height 1:______________

	Trial 1	Trial 2	Trial 3	Total	Average
Crater Diameter (cm)					
Crater Depth (cm)					
Diameter/Depth					
Maximum length of ejected material (cm)					
Maximum velocity of Object (m/s)					

Object 1:_______________ Mass of Object 1:_______________ Height 2:_______________

	Trial 1	Trial 2	Trial 3	Total	Average
Crater Diameter (cm)					
Crater Depth (cm)					
Diameter/Depth					
Maximum length of ejected material (cm)					
Maximum velocity of Object (m/s)					

Object 2:_______________ Mass of Object 2:_______________ Height 2:_______________

	Trial 1	Trial 2	Trial 3	Total	Average
Crater Diameter (cm)					
Crater Depth (cm)					
Diameter/Depth					
Maximum length of ejected material (cm)					
Maximum velocity of Object (m/s)					

DATA ANALYSIS

1. Connect your Labqust 2 to a computer using a USB connection.
2. Open the Logger Pro software.
3. From the menu bar, select “File, LabQuest Browser, Open”
4. Select the file you saved during the lab
5. Choose continue without data collection on the screen that pops up.
6. You should see two graphs, one with position vs. time and on with velocity vs. time.
7. For each Run in the experiment, create 1 graph with both velocity and position.
8. To do this, right click on the graph and select graph options.
9. On the first menu, check the box labeled “Legend” and uncheck the box labeled “Point Symbols”
10. Select the “Axes Options” tab at the top of the menu.
11. Under the Y-Axis Columns, be sure that the boxes labeled “Position” and “Velocity” are checked for run 1.
12. Select “Done” at the bottom of the menu.
13. Your graph should look something like the Figure 2.
14. Record the maximum velocities for each object from each trial in your data tables.

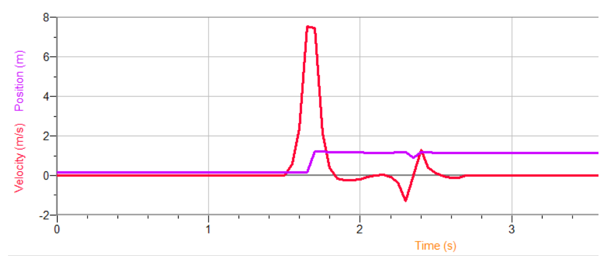


Figure 2: Graph of Velocity and Position vs time.

15. Once the graph is easy to read, right click on the graph and select “copy”
16. Paste the graph into your word document for use in your lab report.
17. Repeat for each run for each object.
18. Use your data and the formula from the lab introduction to determine the amount of kinetic energy of both objects from both heights.

QUESTIONS *(10 points)*

1. Using the graphs you produced, what is the relationship between crater size and velocity of the impactor?

2. Using the graphs you produced, what is the relationship between crater size and mass of the impactor?

3. What do the data reveal about the relationship between ejecta length and velocity of the impactor?

4. What do the data reveal about the relationship between ejecta length and mass of the impactor?

5. The Chelyabinsk meteor was a superbolide caused by a near-Earth asteroid that entered Earth's atmosphere over Russia on 15 February 2013 at about 09:20 YEKT, with a speed of 19.16 kilometres per second (40,000–42,900 mph). It had an estimated mass of 12,500 metric tonnes (1.25×10^{10} g). How much kinetic energy did the Chelyabinsk meteor have when it struck Earth?

What relationships did you observe between the variables?

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What predictions can you make based on your observations?

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CONCLUSION

I accept or reject my hypothesis (circle one)

What evidence did you use to accept or reject your hypothesis?

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How can you use this knowledge?

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Turn in your data table, graph, and answers to the questions above along with your lab report.