Lab #11

Impact Craters

Introduction

It is clear from the surface features of geologically old planets (the Moon, Mercury) and some of the unusual phenomena in the solar system (Earth's large moon, the rotation of Venus) that planetary impacts have played an important role in the history and evolution of the solar system. Despite this, impact craters on Earth were not well-understood until this century. In today's lab, we will study how the characteristics of a crater (particularly its size) can lead a careful observer to many conclusions about the properites of the impactor that made the crater.

When a small object collides with the Earth, it has a certain amount of kinetic energy. This energy depends on the object's mass and its velocity. After the object impacts the Earth, its kinetic energy drops to zero...the object stops moving, but this energy doesn't vanish completely. Instead, the kinetic energy translates into other forms, such as explosive energy, heat and light. This explosive energy will dig out a bowl of material called a crater (the original impactor itself will often remain buried deep underground after the crater is formed).

Often by experimenting on small scales like this, scientists can successfully extrapolate to much larger scale situations, such as impacts of objects with diameters of several miles across. It is this sort of logic that first led scientists to theorize that a large asteroid impact may have resulted in the extinction of the dinosaurs about 65 million years ago. One can calculate the expected kinetic energy of an incoming 10-km diameter asteroid using the same principles as in today's lab. If only a small fraction of that energy is deposited into the Earth's crust and atmosphere and energy, it is easy to imagine a significant portion of life on Earth being destroyed.

Step 1

Our first step is to prepare our "surface" for impacts. Each group of 2-3 students should have a plastic bowl full of fine sand and two small ball bearings made of iron. Your TA will tell you what the mass of each ball bearing is.

Before you start dropping ball bearings into the sand, you'll need to level the surface (by gently shaking the bowl back and forth). This will make it much easier to measure the diameter of the craters you create.

Once you've done this, start filling in the table on your worksheet using the following steps:

- Use your meter-stick to estimate the height of the sand surface above the table top to the nearest centimeter.

- Drop the smaller mass from a height of 20 centimeters above the sand surface.

- Measure the diameter of the crater (to the nearest 0.1 cm).

- ***Repeat this three times*** and average your three results.

  Write your average value in column 4 of the appropriate table with a precision of 0.1 cm.

- Repeat for the larger mass from a height of 20 centimeters above the sand surface. Again, record in your table the average value of three measurements.

- Do similar measurements for masses dropped from each height listed on table. Try to get as many craters as possible measured without having to "reset" the entire surface.

- When the surface is too dense with craters, gently shake the bowl again until the surface is flat and smooth and sprinkle another fine layer of flour on top.

After you've recorded your data in column 4 in each table of the worksheet, fill in columns 5 and 6 as follows:

- Calculate the Kinetic Energy of the impactor using the formula $^1/_2mv^2$.

- Calculate the crater diameter to the third power with your calculator.

Step 2

The volume excavated by the impactor is a half-sphere, so the amount of sand displaced in an impact depends on the diameter of the crater cubed. This volume should be directly proportional to the kinetic energy ($^1/_2mv^2$) of the impactor. Thus, we expect to find a linear relationship between the cube of the crater diameter and the kinetic energy of the impactor. Let's test that by drawing a simple graph using the data from the table we generated in step 1.

- For each of the four rows in each data table, plot a data point on the graph on your worksheet (the y-axis is crater diameter cubed, the x-axis is kinetic energy).

- Draw your best-fit line as close as possible to the eight data points using a straight-edge.

- Calculate the slope of this line using slope = $^{Dy}/_{Dx}$. Write this answer on your worksheet with two significant figures.

Essay

In your first paragraph, discuss the uncertainties in this lab. In particular, provide at least two ways this lab could be done differently that would significantly reduce the amount of error a typical student is likely to achieve. One idea: If you used even more ball bearings with different masses, dropped from different heights, would they still show the same trend as your graph in step 2? Did your plotted points for the two different masses show different slopes or roughly the same slope? Explain.

We can use information like that found in step 2 to estimate the properties of impactors that cause large craters on Earth (where the diameters are measured in kilometers instead of centimeters...the Physics is still the same!). From this kind of analysis, scientists have concluded that an ancient 100-km diameter crater found on the Yucatan peninsula in Mexico was caused by a massive meteorite (more than 1 km in diameter and weighing as much as some of the biggest mountains on Earth) that slammed into the Earth about 65 million years ago. It turns out that such impacts (the type of which can dramatically alter Earth's climate and wipe out a large fraction of life) are thought to occur on the Earth about once every 100 million years.

Given that it would cost our government about $10 million per year to adequately monitor the sky for such impacts (given enough warning, we do have the technology to prevent such impacts), do you think this would be a worthwhile investment? Or would you rather use the money to provide, say, small tax cuts for everyone or build more roads? Explain.

Lab #11 Worksheet

Name:
Home TA:

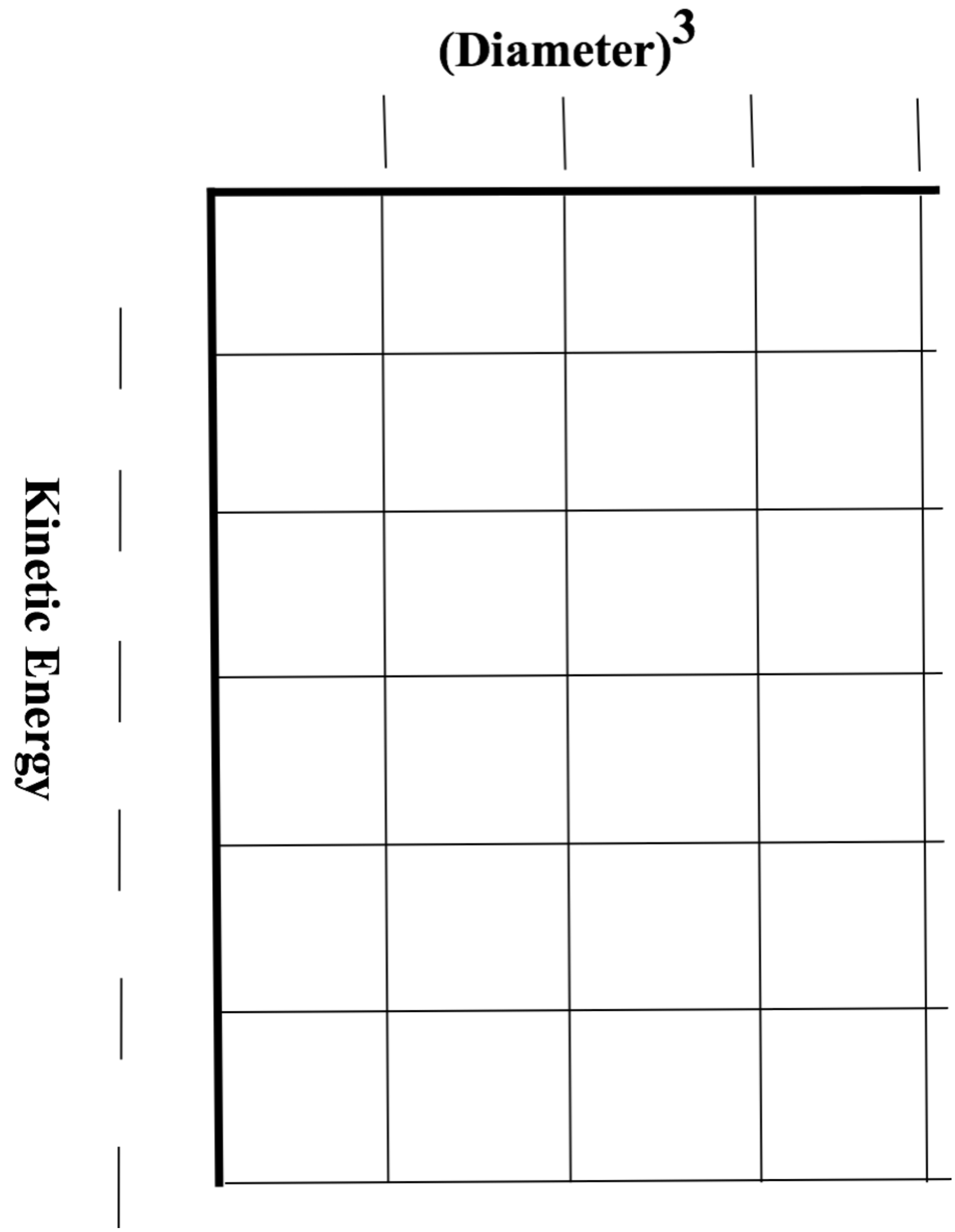
Smaller mass

Mass (grams)	Height (cm)	Velocity (cm/sec)	Average Diameter (cm)	Energy (ergs)	Diameter^3 (cm^3)
	20.	19			
	40.	28			
	60.	34			
	80.	39			

Larger mass

Mass (grams)	Height (cm)	Velocity (cm/sec)	Average Diameter (cm)	Energy (ergs)	Diameter^3 (cm^3)
	20.	19			
	40.	28			
	60.	34			
	80.	39			

Graph of Volume Displaced vs Kinetic Energy of Impactor



Slope of smaller ball = __________ Larger ball = ______________