Impacts from Space

Introduction

Our goal is to discover the relationship between the energy of a meteoroid smashing into the Earth and the size of the crater it makes. We will use ball bearings as mock meteorites to find the relationship and use that data to make some predictions about impacts from more massive objects.

In the ancient world, meteorites were believed to contain supernatural powers. In the 1790s, E. F. F. Chlandi, a German lawyer and physicist, collected evidence suggesting that meteorites originated in space, but the scientific community rejected his hypothesis. Thomas Jefferson remarked, upon hearing a report from two Yale professors regarding the extraterrestrial origin of a meteorite, "It is easier to believe that Yankee professors would lie, than that stones would fall from heaven".

In 1803, a shower of meteorite fragments hit L'Aigle, France. The notoriously skeptical French Academy of Sciences dispatched renowned physicist Biot, who concluded that Chlandi's hypothesis had been correct. The idea that 'stones from heaven' originated in space slowly spread through the scientific community.

Today, astronomers call these 'stones from heaven' *meteoroids* when they are in space, *meteors* while they are passing through Earth's atmosphere, and *meteorites* when they are on the ground. Most meteors are the size of a marble or smaller and last only a few seconds, completely vaporizing in the atmosphere. Larger pieces are only partially vaporized and survive as meteorites.

Craters

Galileo used the word crater (Greek for cup) to describe the circular pits he observed on the moon. We now know that these craters were caused by impacts. They are the result of the conversion of *kinetic energy* to *thermal* and *mechanical energy* at the moment of impact. This process vaporizes a portion of the rock in the Earth's surface. The resulting explosion propels debris out to form the crater shape.

Every few thousand years the Earth is hit by a meteoroid tens of meters or more in size. An impact from a large meteor produces an enormous blast on impact, propelling debris into the atmosphere. One of the most famous meteor impacts is in northern Arizona about 40 miles east of Flagstaff. The crater is about 1.2 kilometers in diameter and 170 meters deep. Scientists estimate that the meteor was 50 meters in diameter and hit the earth about 50,000 years ago.

There is also evidence that at the end of the Cretaceous period (about 65 million years ago) an asteroid or comet hit the earth and caused the extinction of the dinosaurs. This hypothesis is based on traces iridium (an element often found in meteroiods) and shocked quartz (created in cataclysmic impacts) in a layer of clay from 65 million years ago. The "smoking gun" is a fossilized crater centered on the town of Chixulub, a small town in Yucatan, Mexico. The size of the crater (150 kilometers in diameter) suggests that the meteorite was approximately 10 kilometers in diameter.

A meteoroid of this size would produce an explosion equivalent to several billion nuclear weapons. The impact not only created the crater, but blasted substantial amounts of dust and molten rock into the atmosphere. The molten rock would have started fires and the hot fragments would have created poisonous gases that, when combined with water in the atmosphere, would result in acid rain. The nitric acid rain and the dust in the atmosphere would have dropped the temperature of the Earth substantially, causing mass extinctions.

Part 1: Gathering Data and Plotting

Supplies

We are going to gather crater size data by dropping ball bearings into a sandbox. You will need:

1. A box of sand
2. A two meter stick
3. A centimeter ruler
4. Three ball bearings of different masses.

Procedure

1. Weigh your three ball bearings on the scale. Record the results in Table 1

2. You will drop each of the three balls from three different heights (nine drops total). Make sure that *at least* one height is less than one meter and *at least one* is greater than one meter and that all are **LESS THAN TWO METERS**. Record your chosen heights in Tables 2, 3, and 4.

3. Perform your nine trials by dropping the ball bearings into the sand. Measure each crater and record its size in the appropriate spot in Table 2, 3, or 4.

4. Calculate the *gravitational potential energy* (PE) of each trial, using the equation:

   $$PE = mgh$$

   where m is the mass in grams, g is the acceleration due to gravity in centimeters per second squared (g = 9.8 m/s^2; you will need to convert), and h is the height above the ground in centimeters. **Record your answer in scientific notation and limit yourself to 3 significant figures.**

5. The relationship between energy and crater size is non-linear, so we will plot our data on log-log paper. If you are unfamiliar with log-log paper, your lab instructor will assist you. Plot each trial on Graph 1.

Part 2: Analysis

Two quantities are **correlated** if the value of one can be estimated from the value of the other. For example, the height and weight of people are correlated; tall people tend to weigh more than short people. It is extremely rare to find a person 6'6" tall who weights only 50 Ibs. Likewise, it would be unlikely to find a person 4' 6" who weighs 400 Ibs.

One way to show a correlation is by looking at a graph of with one quantity on the x axis and one on the y axis. If a pattern emerges, then a correlation exists and knowledge of one value can be used to **predict** the other.

Procedure

1. Draw a **best fit** line through your data points. Extend the line past the top and bottom of the graph.

2. Using your best fit line, find the crater diameters when the energy is 1×10^5 ergs and 1×10^8 ergs. Record the results at the bottom of Graph 1.

3. Plot the two points that you recorded at the bottom of Graph 1 onto Graph 2. The gray box on Graph 2 is the area that Graph 1 would occupy. Draw a line on Graph 2 connecting these two points and extend it to the top of the graph.

4. Answer the questions after the graphs.