ESA21
Environmental Science Activities for the 21st Century

Table of Contents:

(1.) Introduction and Background Notes
(2.) Testing Factors that Affect Impact Crater Size
(3.) Experimenting with Impact Craters
(4.) Experiment 1: General Comments
(5.) Experiment 1: Tables and Graphs
(6.) Data Analysis, Evaluating Design, Analyzing Assumptions
(7.) Experiment 2: Procedures

Introduction and Background Notes

Central to good science are accurate observations, testable hypotheses, well-designed experiments or other tests, and reasonable data analyses. The purpose of Laboratory 1 is to introduce you to the basics of designing and analyzing experiments. The following two laboratory exercises will provide you with further steps in organizing and analyzing data. Many interesting experiments are impossible to do in a normal undergraduate science laboratory setting. For this reason, your introduction to designing an experiment that has relevance in "the real world" involves a computer simulation. This program will allow you to create a virtual impact crater on Earth.

Have you seen any disaster movies lately? You know the kind, where some great catastrophe is about to befall all of humanity and threaten the very existence of life on Earth? Movies such as "Armageddon" and "Deep Impact" depict Hollywood's take on the effects of an asteroid or comet that is on a collision course with Earth. How realistic are these films? What would the effects of such an impact really be? Are they relevant to real life?

Meteorite impacts have been getting plenty of attention in recent years. They are regarded by the public as the annihilator of dinosaurs and as the potential destroyer of civilization. Scientists understand that impacts are an integral part of the processes that formed the solar system, and which continue to modify planets more than four billion years later. Additionally, meteorite impact events have influenced the biological history and diversity of life on Earth; understanding them may be particularly relevant to our own survival.

Researchers monitor the skies, counting and tracking asteroids and comets that are likely to cross Earth's path, as it makes its yearly trip around the Sun. Why? There are many other objects orbiting the Sun, besides our home planet: seven other planets, tens of moons, and thousands of asteroids, to name a few. There are still other objects orbiting the Sun; some of these are called Earth-crossing asteroids, because they have elliptical orbits that cross the orbit of Earth and the other inner planets. These asteroids may come very close to Earth, and occasionally there is a collision. Therefore, there is some rationale to studying them, beyond mere scientific curiosity. Researchers hope to identify any potential collision, before it actually happens. Remember the premise to those science fiction films?

A **meteorite** is a general term for any extraterrestrial object, regardless of its size or composition, which is large enough to strike Earth's surface and to make a crater. An **impact crater** is formed when a meteorite (asteroid or comet) crashes into a larger planetary body that has a solid surface, such as the Earth. Impact craters cover the surface of the moon, and have been identified on all of the rocky bodies of the solar system. Currently, about 160 impact craters have been identified on Earth's surface. You can see a map of their locations here: http://www.lpi.usra.edu/publications/slidesets/craters/slide_2.html

One of the best known impact craters is Barringer Crater in Arizona. It is nearly 1.2 kilometers across and some 170 meters deep. The crater was formed approximately 49,000 years ago by the impact of a nickel/iron meteorite 50 meters in diameter, traveling at a velocity of 11 kilometers per second. You can check it out for yourself. Visit http://www.meteorcrater.com/ for a short animation and more information.

Massive impacts are devastating events. The impact itself causes destruction, but the after effects are just as catastrophic. A massive blast wave and tremendous explosion occurs as the meteorite punches through Earth's atmosphere and smashes into the surface. If the impact occurs on land, massive earthquakes, up to magnitude 13 on the Richter scale, would be produced, along with numerous large magnitude aftershocks. Global wildfires likely follow, as biomass near the impact site ignites. If the impact occurs in the oceans, huge tsunamis would be generated and the 'splash' from these could reach the height of a jet plane. Surface materials at the site of impact are vaporized, and in either case, great quantities of smoke, dust, and gases are thrown upward into the atmosphere. This material would block out solar radiation, producing a cooling effect and disrupting photosynthesis, seriously disrupting all ecosystems as these organisms are at the base of the food chain. The dust would take months to settle back to the surface. During this time, the world would be in a state of continuous darkness and globally, temperatures would drop causing winter-like conditions throughout the world.

Testing Factors that Affect Impact Crater Size

When an Earth-crossing asteroid is identified as a possible Earth-impactor, scientists need to determine if the characteristics of the asteroid are such that an alarm needs to be sounded. Scientists have identified asteroids (and meteorites) of all sizes, ranging from micro-meteorites, only a few micrometers in diameter, to small rocks a few centimeters to meters in diameter, to asteroids several kilometers across. Asteroids and meteorites may have different compositions, be traveling at different velocities, and may strike the Earth at almost any angle. Many meteorites impact Earth each year. Most of these are small enough that they burn up in the atmosphere. You may have even seen one yourself, more commonly called a "shooting star." If an asteroid is very large, however, it may survive the frictional heating of the atmosphere and strike Earth's surface, creating an impact crater. These are the ones that get the most attention.

Experimenting with Impact Crater Size

What factors affect the size of an impact crater? Why are some impact craters bigger than others? How much damage can be expected if a “big one” does strike Earth? There are at least five factors that affect the size, shape and depth of a crater that is formed by the impact of an asteroid with Earth: (a) the asteroid diameter, (b) the density of the asteroid, (c) the velocity of the asteroid as it encounters Earth’s atmosphere, (d) the angle at which the asteroid approaches Earth’s surface, and (e) the density of the material that the asteroid strikes at Earth’s surface.

In this lab, we will test whether different factors affect the size of an impact crater through the use of a computer simulation. In the process, we will also discuss the basics of designing an experiment. We will begin by discussing, running, and analyzing one experiment. You will then design, run, and analyze a second experiment.

Hypothesis

Experiments are designed to test particular hypotheses. A hypothesis is a reasonable explanation for an observation, an "educated guess." To be considered a scientific hypothesis, it must be testable; that is, there must exist the possibility of disproving it. Many hypotheses may be proposed to explain a particular phenomenon, just as we gave five possible explanations for how the different characteristics of a meteorite which strikes Earth can change the size, shape, and depth of the resulting impact crater. One way to state the explanation, or hypothesis, we have chosen to test is:

Hypothesis: The characteristics of a meteorite affect the impact crater size.

Predictions

To test a hypothesis, predictions are made and experiments are performed. A prediction is a statement of what will happen under certain circumstances if the hypothesis is true. It is a necessary consequence of the hypothesis. For example, in testing this hypothesis, we would predict that if we change the speed of the meteorite, then there would be a change in the size of the resulting impact crater.

There are many factors we could test – initial velocity, angle of impact, density of target material, meteorite size, and so forth. If we changed them all at the same time, we would not know which one of them caused any observed changes. Hence, we will test only one factor at a time. One of the factors in this simulation that is easy to change is asteroid velocity, so in our first experiment, that will be the factor we manipulate.

How will we measure impact crater size? The width of the outer rim of the crater could be measured, as well as the depth of the crater. The energy released by the force of the impact could be calculated, and damage resulting from the blast could also be determined. The particular program that we are using will simulate all of these results. An especially fun feature of this simulation is that it allows you to select the site of the impact using imagery from GoogleEarth, and view the resulting crater diameter. Crater width or diameter is also reported as a calculated value. This means that crater diameter would be a good variable for us to measure.

Given this information, it should be easy to see that, if the hypothesis is correct, then we should be able to see differences in the crater diameters that result from the impacts of asteroids having different initial velocities.

Prediction 1: Meteorites striking Earth at different velocities will result in impact craters of different diameters.

Procedure
The Impact Calculator simulates the impact of an asteroid on Earth, under a variety of conditions. For the test of the first prediction, we will select an asteroid of some diameter, and send it hurtling toward Earth at different velocities while keeping all other factors the same.

Variables
There are three types of variables to consider in conducting a scientific experiment. The independent variable is the factor that is intentionally made different at the beginning of the experiment, and at least two different cases (velocity) of that factor must be examined. More cases will usually support your conclusion better. In the first prediction, the independent variable is velocity, so we will bombard Earth with asteroids traveling at different velocities. How will we decide which ones? When an asteroid strikes another rocky body, such as the Earth, the result is an explosive collision which carves out an impact crater. These collisions occur at very high velocities, ranging between 11.2 kilometers per second (the escape velocity of the Earth-Moon system), and 72 kilometers per second (the orbital velocity of the Earth plus the escape velocity of the solar system at the distance of the Earth from the Sun). [(1)] Note that scientists use the metric scale for measuring dimensions and velocities. This simulation will allow us to test velocities ranging from 0 km/s to 60 km/s. If we test at 5 km/s intervals, that will give us twelve different cases – enough to see any basic patterns emerge.

A second type of variable is the dependent variable. This is the variable that is measured to see if changing the independent variable had an effect. It is the kind of data that is being collected. In the first prediction, the dependent variable is the crater diameter at the end of the experiment. Since the projectile densities, trajectory angles, and diameters of the asteroids we will test are all the same, any variations in the diameter of the resulting impact craters should be due to the change in velocity.

The third type of variable is a controlled variable, and any given experiment will have several. Controlled variables are the factors that might affect the dependent variable and that therefore must be consistent for all cases of the independent variable tested. In testing prediction 1, for example, each trial uses an asteroid or projectile that has the same density, diameter, and trajectory angle. The target material density is the same in each case as well. Anything that might affect the resultant impact crater diameter, other than projectile velocity, must be identical for all velocities tested.

(1) http://www.lpi.usra.edu/publications/slidesets/craters/index.shtml

Experiment 1: General Comments
A computer simulation will be used to test each of the predictions. The particular program you will use has been programmed to simulate a variety of initial projectile conditions as well as target conditions on Earth. The projectiles are assumed to be asteroids or comets, rather than man-made space debris, such as old satellites or defunct space stations. Asteroids are thought to represent material that was left over from the formation of the solar system, and consequently, are composed of materials similar to those that formed the planets. This means that the densities of asteroids may vary from ices (similar to comets and the bodies of the outer solar system), to rocks (similar to the surface of the moon or Earth), to that of dense metals, such as we might find in Earth's core. Each run simulates a single impact event. All factors of the collision are controlled except projectile velocity, projectile trajectory, asteroid density and diameter, target material density, and location of the impact event. You can set each of these for each run of the experiment.

All units in the program are in the metric system. The depth of the impact crater, for example, is measured in meters. A meter is a unit of length, and to give you an estimate of its size, it is roughly equal to one yard, or three feet. The diameter or width of the impact craters is measured in meters or kilometers. There are one thousand meters in a kilometer. One kilometer is equal to 0.62 miles (just over half of a mile), or almost as long as eleven football fields, stretched end to end.

Density is measured in kg/m^3. Water has a density of 1000 kg/m^3 or 1 gram $/cm^3$. A gram is a unit of mass, and, to give you an estimate of its size, the average soup can holds about 430 grams of veggies and broth. A kilogram is equivalent to 1000 grams.

The impact event will likely cause an earthquake. In this simulation, earthquakes are measured using Richter magnitude. For example, the earthquake that struck Port-au-Prince, Haiti in January, 2010, measured 7.0 on the Richter magnitude scale.

The amount of energy released by an impact event is measured in joules. One joule is defined as the amount of work done by a force of one Newton moving an object through a distance of one meter. For example, one joule is equivalent to the energy required to raise an apple one meter straight up, or equivalently, the energy released by dropping an apple from a height of one meter. In terms of an impact event, one joule is a very small amount of energy. Because the amount of energy released in an impact-cratering event is so large, the quantity of energy released is reported using scientific notation. Scientific notation is used to express (in this case) very large, or in other instances, very small, numbers. A number written using scientific notation is written as the product of a number and a power of ten. The number has one digit to the left of the decimal point. This is multiplied by a power of ten, indicating how many places the decimal point was moved. For example, the number 65,000,000 written in scientific notation would be $6.5x10^7$ because the decimal point was moved 7 places to the left to form the number 6.5. It is equivalent to 6.5 x 10 x 10 x 10 x 10 x 10 x 10 x 10.

The terms impact crater 'width' and 'diameter' are, for our purposes, essentially the same measurement.

To test the first prediction, you will create several virtual impact craters by running the simulation twelve times, each at a different velocity. You will keep all other conditions the same. Your data will be recorded on a data table (Table 1-1 in the Data section of this lab).

Accessing the Impact Calculator:
You may access the Impact Calculator by following this link: **Down 2 Earth Impact Simulator** Computer simulation of asteroid impact that enables users to alter parameters. *Faulkes Telescope* http://simulator.down2earth.eu

Running the Impact Calculator:	
	Once you are on the first screen:
(1.)	Select the language that you will use.
(2.)	Select “Start” by pointing to it with your mouse or cursor, and click it once.
(3.)	This screen will allow you to set your initial input parameters for each run of the experiment.
(4.)	Set the “Asteroid Diameter” by sliding the pointer to the right, until the diameter value reads “1000 m.” We will use a starting diameter of 1 km, as this is a reasonably common size for a typical asteroid.
(5.)	Next, set the “Trajectory Angle.” This is the angle at which the asteroid will hit Earth’s surface. Let’s keep it simple and assume a direct hit. Slide the pointer until the value = 90 degrees.
(6.)	Select the “Projectile Density.” This is the density of the asteroid. Click on the “Please select” box and then select “Dense Rock” from the drop-down menu.
(7.)	Next, select the “Target Density”. This is the type of material that the asteroid will encounter at Earth’s surface. Click on the “Please select” box, and then select ‘Sedimentary Rock’ from the drop-down menu.
(8.)	Select the “Object Velocity”. This is the velocity that the asteroid will be traveling as it encounters Earth’s atmosphere. Move the pointer until the value reads 5 km/s.
(9.)	Select an observation point, from which you will compare and observe the effects of the impact. At the bottom of the screen, select the “Distance from crash site,” by moving the slider to the right. Choose an observation distance between 75 km and 100 km.
(10.)	Select “Submit.”
(11.)	A new screen appears which details the Calculation Results. This is the “Crater Size” view. Impact values are listed here.
(12.)	Select “Barringer Meteor Crater, AZ” from the drop-down menu. (Other cities and terrestrial impact craters are available by scrolling down the menu, or clicking and dragging the map image. Barringer Crater is a good place to start, as it gives us a nice reference point for comparison.)
(13.)	Click the map image to indicate the location of your virtual impact crater.
(14.)	Record the crater width at 5 km/s, Trial 1, on Table 1-1. (If a crater is not formed, record a zero).
(15.)	Select “Crater Depth” at the bottom of the screen. This will bring you to a new screen, which illustrates your virtual impact crater in a profile view.
(16.)	Select a landmark for comparison, by using the drop-down menu. Please select the Empire State Building. Observe the depth of your crater compared to the landmark.
(17.)	Select “Data View” at the bottom of the screen. This will bring you to a new screen. Here, your initial values of asteroid mass, projectile velocity, trajectory angle, projectile density, and target density are listed.

	Damage that occurs at the chosen observation distance (between 75 and 100 km) from the crash site is described. Information regarding the impact energy of the impact event, and frequency of occurrence is also provided.
(18.)	Select “Go Back” to return to the Input Parameters page. Notice that the conditions set are the same as those for the test you just ran. Do not change the conditions for asteroid diameter, angle, density, or target density.
(19.)	For the second trial, change only the “Object Velocity,” until it reads “10 km/s”. Then Select “Submit.” Record the results on Table 1-1.
(20.)	Select “Go Back” to return to the “Input Parameters” page.
	Continue in this fashion, repeating steps 8 – 18, each time changing only the velocity. Use the velocities listed on Table 1-1. Record the results on Table 1-1.

Experiment 1: Data Tables
Data tables are a good way to record and organize data. In most experiments, there are two kinds of data. The first is raw data, the data you are taking directly from your experiment. Often, this is sufficient, but there are times when data must be further processed to be useful. In the real world, there are likely to be variations in the shape of the asteroid. Perhaps it has an oblong shape or the composition (and therefore mass) is distributed unevenly. There are also likely to be variations in the composition of the target material. Can you think of other sources of variability or random error? If these sources of variability were taken into account when designing the simulation, the resulting crater measurements generated with each run might be slightly different. The experiment would have to be run several times, and the results for each trial velocity would have to be averaged, yielding a more accurate measurement for comparison. Unfortunately, this simulation does not account for random error in this manner and returns only one value for each set of parameters.

Data tables are set up after the experiment has been designed and before the data are taken. Each should have a title that includes both the independent and the dependent variable and that reflects the experiment. Columns and rows should also have appropriate labels. A data table for the first prediction is supplied for you to use.

Experiment 1: Graphs
Although a table is very useful for organizing data, graphs can often help to clarify the relationships between the independent and the dependent variables by depicting them visually. When graphing the results of an experiment, the dependent variable is represented on the vertical or Y-axis and the independent variable on the horizontal or X-axis. The title of a graph is similar to that of a table and should include both the independent and dependent variables. Both axes should be labeled. Be sure to include the units of measurement. In this case, the titles and labels for the first prediction and test are supplied for you, but you must complete these items for later graphs. You should decide on the scale for each graph. Remember to spread the scale for each axis over the space allotted rather than using only the bottom half or the left half of the graph.

Data Analysis
Once you have completed an experiment, you can determine whether or not the data support or do not support the hypothesis. In this case, for example, if the width of the impact crater varied significantly when formed by an asteroid moving at different velocities, the hypothesis has been supported. If the crater diameter is about the same in every case, then the hypothesis has not been supported.

Once you have completed taking the data for an experiment, you must decide if it supports the hypothesis. To report this to someone else, your analysis must include a bit more than just your conclusion – it should also include your reasoning. For this reason, a good analysis: (1) begins with a statement of the hypothesis, (2) indicates the kind of data that would support the hypothesis (the prediction), (3) cites the relevant data that were collected (gives examples that illustrate the trend you see), and (4) draws a conclusion as to whether or not the hypothesis was supported. Remember, a hypothesis is only a possible explanation that is being tested and the purpose of this argument is to convince the reader that the evidence either does or does not support the hypothesis.

Evaluating the Design of an Experiment

Analyzing the data from an experiment is only one important aspect in evaluating what it says about the hypothesis. It is also important that the experiment be a good one. If an experiment is flawed, the data cannot be completely trusted and may therefore lead the investigator to an incorrect conclusion.

While doing a complete analysis of the experimental design may take an expert, there are four common criteria we can apply:

(1.) Is there only one independent variable and why do you think it is an appropriate one for testing the hypothesis?

(2.) Is the dependent variable accurately measured and why do you think it is an appropriate one for testing the hypothesis?

(3.) Are all of the other potentially important variables controlled (maintained the same in all cases of the independent variable)?

(4.) Is there enough data?

Notice that none of these criteria judge the experiment on the basis of whether or not it supported the hypothesis. An experiment is a way to ask if the hypothesis is correct. The validity of the experiment is independent of the conclusion. Let's look again at each of these criteria, see what they mean, and use them to examine the first experiment from this lab. Then you will be asked to evaluate the experiment you designed. In answering these questions, it will be helpful to remember the hypothesis and the first prediction.

Hypothesis: The characteristics of a meteorite affect the impact crater size.

Prediction 1: Meteorites striking Earth at different velocities will result in impact craters of different diameters.

(1.) Is there only one independent variable and why do you think it is an appropriate one for testing the hypothesis? In answering this question you should identify the independent variable and explain why you think manipulating it is a case of changing environmental conditions. In the first experiment, velocity is the independent variable, and it is the only variable we purposely changed. We chose velocity because it is clearly a characteristic of the meteorite forming the impact crater.

(2.) Is the dependent variable accurately measured and why do you think it is an appropriate one for testing the hypothesis? In answering this question, you should identify the dependent variable, indicate why you think it was or was not accurately measured, and indicate why you think measuring it is a way to measure the dependent variable of the hypothesis. In the first experiment, the dependent variable was the impact crater diameter. This is appropriate because it is a commonly accepted way of measuring impact crater size. We cannot comment on accuracy because the computer program does not give us any information on this.

(3.) Are all of the other potentially important variables controlled (maintained the same in all cases of the independent variable)? In answering this question, indicate what variables were controlled and how. In testing the first prediction, you know that projectile density, trajectory angle, asteroid density, and target material were all held constant for each run of the simulator.

(4.) Were enough data collected and why do you think this? There must always be enough data collected to reflect the actual situation. Questions to ask yourself include whether there are enough replicates of each test as well as whether or not enough cases of the independent variable were tested. In Prediction 1, for example, is one replicate sufficient for each velocity tested? Probably not, if this were a study for the Department of Defense, but in this case we can accept it because this simulator always yields the same crater diameters for the same initial conditions. Another question to ask is whether or not enough different velocities were tested and was a wide enough range used. Since most meteorites travel at velocities between 11 km/s and 70 km/s, that range should be sufficient. Twelve equally spaced velocities were tested and provided a clear trend in the data.

Assumptions of an Experiment

Another factor that affects the conclusions we draw from an experiment are whether or not the assumptions are reasonable. Assumptions are factors that are thought to be true for the investigation but that have not been verified or controlled. They may include information that is commonly accepted and seems to need no further confirmation, such as one massive object hitting another at a high rate of speed is likely to cause some damage. Sometimes assumptions are variables that are thought to be held constant but that are not checked, such as the density and thickness of the atmosphere. They may be factors that are beyond the control of the investigator because of technical or time considerations. For example, if we are doing this experiment in order to find the set of conditions that will provide the threshold for surviving an impact event, we are assuming that the trends observed for one land location would be the same as those observed if we ran the test for any other location on land, since that is where most people live. Incorrect assumptions invalidate the investigation. All scientific tests are based on some assumptions that must be identified and considered in the analysis.

Deciding if the assumptions are reasonable is called justifying the assumptions. Justifying an assumption involves indicating (a) why it is important to the experiment and (b) why it probably is or is not true.

In the first experiment, the following are among the assumptions and justifications:
(1.) *The resultant impact crater dimensions examined are typical and representative of all impact craters on Earth*. The hypothesis is a generalization meant to apply to most terrestrial impact craters. If the craters examined are not typical, the results will be true only for some craters in certain locations rather than for most craters. The assumption is reasonable to accept, however, because the conditions simulated are similar to most land areas on Earth.
(2.) *The set of meteorite characteristics that affect impact crater size are not variable with time*. The meteorite does not alter its composition, mass, velocity, or trajectory angle, unless acted upon by an outside force. If the characteristics that affect impact crater size are variable over time, then the trends detected are valid only for those impact events which occur before meteorite modification occurs. Experience with other observed and collected meteorite

specimens tells us that meteorites do not alter their chemical compositions, mass, or densities on human timescales. It is therefore reasonable to accept this assumption.
(3.) Meteorites have mass, and are thus uniformly accelerated by gravity, on Earth and everywhere else in the universe. If this assumption is false, any conclusions we reach cannot be applied beyond the conditions of the experiment. The primary factor here is the acceleration due to Earth's gravity, which is considered to be a constant variable in this experiment. If the experiment were conducted on another planetary body, such as the Moon, then the acceleration due to gravity would have to be adjusted to reflect the smaller mass of the Moon.

At this point, refer to the lab printout sheet and complete the section for Experiment 1.

Experiment 2: Procedures
A hypothesis that has been tested only once usually remains a hypothesis until it has been tested many times. If the tests provide convincing evidence that the hypothesis is correct, then it is considered to be true until (and if) convincing contradictory evidence emerges. If the tests provide convincing evidence that the hypothesis is not correct, it is either dropped from consideration or changed and retested. In other words, a reasonable hypothesis is usually tested many times.

For the second part of this laboratory, you are being asked to use the Impact Calculator to choose and test a second prediction from the original hypothesis. Recall, the hypothesis is:

Hypothesis: The characteristics of a meteorite affect the impact crater size.

There are four other factors you can choose to test using this program – asteroid diameter, trajectory angle, projectile density, and target density. Pick one of these, make a prediction about it, and design an experiment. Then run your experiment using the Impact Calculator. Remember that you will have to set each of the elements in the program (density, velocity, etc.) to the desired level.

Refer to the lab printout sheet and complete the section for Experiment 2.

ESA 21: Environmental Science Activities

Activity Sheet
Experimental Analysis

Name:

Instructor:

Experiment 1:

Table 1-1: The Effects Velocity on Impact Crater Size

Velocity	Impact Crater Diameter (meters)
5 km/s	
10 km/s	
15 km/s	
20 km/s	
25 km/s	
30 km/s	
35 km/s	
40 km/s	
45 km/s	
50 km/s	
55 km/s	
60 km/s	

Answer these questions for the first experiment examining the relationship between the velocity of the impacting asteroid and the final diameter of the impact crater.

1. What is the independent variable for this experiment?

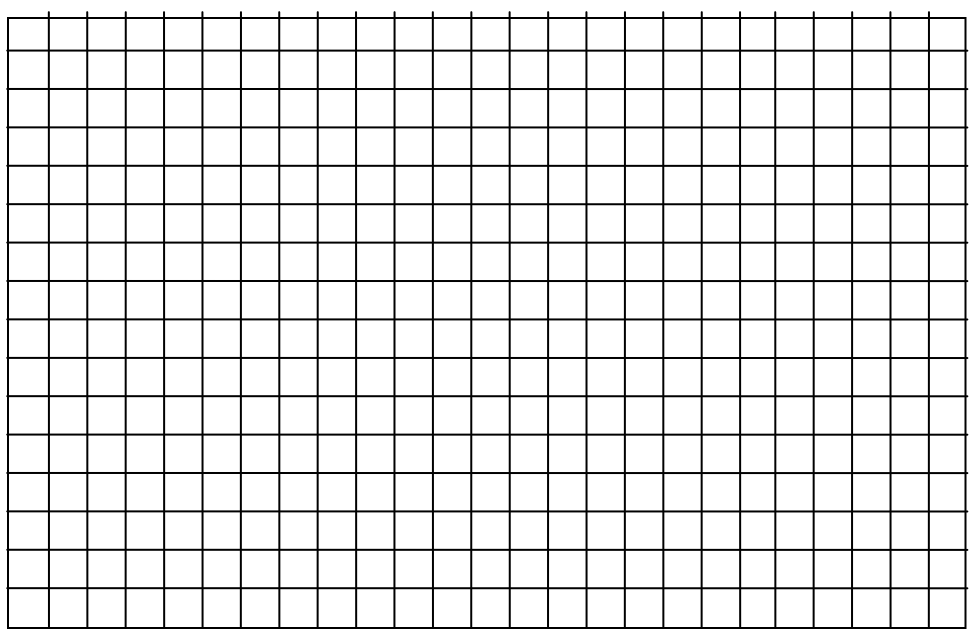
2. What is the dependent variable for this experiment?

3. List at least four controlled variables for this experiment

4. Using the data you collected for your experiment, complete the graph below for this experiment.

Graph 1-1 The Effects of Velocity on Impact Crater Size

Impact Crater
Diameter
(meters)



Velocity in km/s

Experiment 2:

In the second part of the laboratory, you designed your own test of the hypothesis: **The characteristics of a meteorite affect the impact crater size.** All of the questions on this sheet refer to the experiment you designed.

5. What was your prediction?

6. What is the independent variable for your experiment?

7. What is the dependent variable for your experiment?

8. List at least four controlled variables for your experiment

9. Using the data you collected for your experiment, complete the table and graph on the next page, then write an analysis of your data here.

Table 1-2

TITLE: ____

Independent Variable is: ______________	Impact Crater Size (meters)

Graph 1-2

Title: ____

Y-Axis
Label:

______

____

Label X-axis: ____