LAB 2

Lab Handout

Lab 2. Acceleration and Gravity: What Is the Relationship Between the Mass of an Object and Its Acceleration During Free Fall?

Introduction

The motion of an object is the result of all the different forces that are acting on the object. If you push a toy car across the floor, it moves in the direction you pushed it. If the car then hits a wall, the force of the wall causes the car to stop. Applying a push or a pull to an object is an example of a contact force, where one object applies a force to another object through direct contact. There are other types of forces that can act on objects that do not involve objects touching. For example, a strong magnet can pull on a paper clip and make it move without ever actually touching the paper clip. Another example is static electricity. Static electricity in a rubber balloon can cause a person's hair to stand up without the balloon actually touching any of his or her hair. Magnetic forces and electrical forces are therefore called non-contact forces. Perhaps the most common non-contact force is gravity. Gravity is a force of attraction between two objects; the force due to gravity always works to bring objects closer together.

Any two objects that have mass (and, remember, all matter has mass) will also experience a gravitational force of attraction between them. Consider the Sun, the Earth, and the Moon as examples. The Earth and the Moon are very large and have a lot of mass; the force of gravity between the Earth and the Moon is strong enough to keep the Moon orbiting the Earth even though they are very far apart. Similarly, the force of gravity between the Sun and the Earth is strong enough to keep the Earth in orbit around the Sun, despite the Earth and the Sun being millions of miles apart. The force of gravity between two objects depends on the amount of mass of each object and how far apart they are. Objects that are more massive produce a greater gravitational force. The force of gravity between two objects also weakens as the distance between the two objects increases. So even though the Earth and the Sun are very far apart from each other (which means less gravity), the fact that they are both very massive (which means more gravity) results in a gravitational force that is strong enough to keep the Earth in orbit.

The gravitational force that acts between any two objects, as noted earlier, can cause one of those objects to move. For example, a cell phone in free fall (see Figure L2.1) moves toward the center of the Earth because of gravity. Scientists describe the motion of an object in free fall by describing its velocity and acceleration. Velocity is the speed (distance in a specific amount of time) of an object in a given direction. Acceleration is the rate of change in velocity per unit time, most often the rate of change in velocity per second. The amount of force required to produce a specific acceleration in the motion of an object,

such as a cell phone, depends on the mass of that object. Therefore, as the mass of an object increases, so does the amount of force that is needed to produce a specific acceleration.

FIGURE L2.1
A cell phone in free fall

In this investigation you will have an opportunity to explore the relationship between the mass of an object and its acceleration due to gravity during free fall. Many people think that heavier objects accelerate toward the ground faster than lighter ones because gravity will act on heavier objects with more force. Heavier objects will therefore have a greater acceleration because of the force of gravity. Other people, however, think that heavier objects have more inertia (the tendency of an object to resist changes in its motion) so heavier objects will be less responsive to the force of gravity and have a smaller acceleration. Still others think that mass of a falling object has no effect on acceleration due to gravity because the magnitude of the force of gravity acting on a falling object is dependent on the mass of that object. In this case, the greater force of gravity for a more massive object is countered by the greater inertia of the massive object, thereby resulting in an acceleration due to gravity that is unaffected by the falling object's mass.

Unfortunately, it is challenging to determine which of these three explanations is the most valid because objects encounter air resistance as they fall. Air resistance is the result of an object moving through a layer of air and colliding with air molecules. The more air molecules that an object collides with, the greater the air resistance force. Air resistance is therefore dependent on the velocity of the falling object and the cross-sectional surface area of the falling object. Since heavier objects are often larger than lighter ones (consider a bowling ball and a marble as an example), it is often difficult to design a fair test of these three explanations. To determine the relationship between mass and acceleration due to gravity, you will therefore need to design an experiment that will allow you to control for the influence of air resistance.

Your Task

Use what you know about forces and motion, patterns, and rates of change to design and carry out an experiment to determine the relationship between mass and acceleration due to gravity.

The guiding question of this investigation is, ***What is the relationship between the mass of an object and its acceleration during free fall?***

LAB 2

Materials

You may use any of the following materials during your investigation:

- Safety glasses or goggles (required)
- Beanbags A, B, C, D, and/or E
- Meterstick
- Stopwatch
- Electronic or triple beam balance
- Masking tape

If you have access to the following equipment, you may also consider using a video camera and a computer or tablet with video analysis software.

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Do not throw the beanbags.
3. Do not stand on tables or chairs.
4. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and conduct an experiment as part of your investigation. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What information will you need to be able to determine the acceleration of a falling object?
- Which factor(s) might control the rate of change in the velocity (i.e., acceleration) of a falling object?
- What will be the independent variable and the dependent variable for your experiment?
- Will you measure acceleration directly or will you have to calculate it using other measurements?

To determine *how you will collect the data,* think about the following questions:

- What variables will need to be controlled and how will you control them?

- How many tests will you need to run to have reliable data (to make sure it is consistent)?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data,* think about the following questions:

- How will you calculate the acceleration of a falling object?
- What types of patterns might you look for as you analyze the data you collected?
- What type of calculations will you need to make to take into account multiple trials?
- What types of graphs or tables could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

- the difference between laws and theories in science, and
- the difference between data and evidence in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L2.2.

FIGURE L2.2
Argument presentation on a whiteboard

The Guiding Question:	
Our Claim:	
Our Evidence:	Our Justification of the Evidence:

Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your

ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!