Lab Handout

Lab 7. Mass and Free Fall

How Does Mass Affect the Amount of Time It Takes for an Object to Fall to the Ground?

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 will also have a gravitational force of attraction between them. Consider the Sun, Earth, and Moon as examples. Earth and the Moon are very large and have a lot of mass; the force of gravity between Earth and the Moon is strong enough to keep the Moon orbiting Earth even though they are very far apart. Similarly, the force of gravity between the Sun and Earth is strong enough to keep Earth in orbit around the Sun, despite 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 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 Earth in orbit.

FIGURE L7.1

These skydivers are falling toward Earth because of gravity.

The gravitational force that acts between two objects, as noted earlier, can cause one of those objects to move. The skydivers in Figure L7.1, for example, are moving toward the center of Earth because of the force of gravity. Scientists describe the motion of an object by describing its speed, velocity, and acceleration. Speed is the distance an object travels in a specific amount of time. Velocity is the speed of an object in a given direction. Acceleration is the change in velocity divided by time. The amount of force required to change

the motion of an object 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 change its motion.

In this investigation you will have an opportunity to explore the relationship between mass and the time it takes for an object to fall to the ground. Many people think that heavier objects fall to the ground faster than lighter ones because gravity will pull on heavier objects with more force, so the heavier object will accelerate faster. Other people, however, think that heavier objects have more inertia (the tendency of an object to stay still if it is still or keep moving if it is currently moving) so heavier objects will be less responsive to the force of gravity and take longer to accelerate. Unfortunately, it is challenging to determine which of these two 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 speed of the falling object and the surface area of the falling object. Since massive objects are often larger than less massive ones (consider a bowling ball and a marble as an example), it is often difficult to design a fair test of these two explanations. To determine the relationship between mass and the time it takes an object to fall to the ground, 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 the time it takes an object to fall to the ground.

The guiding question of this investigation is, **How does mass affect the amount of time it takes for an object to fall to the ground?**

Materials

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

- Beanbag A
- Beanbag B
- Beanbag C
- Meterstick
- Stopwatch
- Electronic or triple beam balance
- Masking tape
- Safety glasses or goggles

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 activity.

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 will serve as your independent variable?
- What will serve as your dependent variable?
- What measurements will you need to determine the rate of a falling object?

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

- How will you calculate the rate of a falling object?
- 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 Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

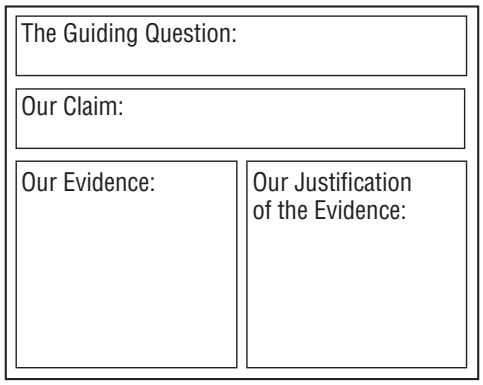
- the importance of looking for and understanding patterns in data,
- the importance of understanding proportional relationships in science,
- the difference between laws and theories in science, and
- the difference between data and evidence in science.

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 L7.2.

FIGURE L7.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member 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 arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?

- How confident are you that your claim is valid? What could you do to increase your confidence?

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 most acceptable and valid answer to the research question!

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 and valid!