LAB 9

Lab Handout

Lab 9. Falling Objects and Air Resistance: How Does the Surface Area of a Parachute Affect the Force Due to Air Resistance as an Object Falls Toward the Ground?

Introduction

When we solve motion problems in physics, we often neglect to take into account the effects of air resistance because, at slow speeds, they are relatively small compared with the force of gravity. Other times, we ignore air resistance when we perform calculations in order to simplify the problem. However, some devices like kites and parachutes are designed to use air resistance in order to function. In these cases, scientists need to account for the effect of air resistance on falling objects.

FIGURE L9.1

An airdrop of food and medical supplies after a major earthquake in Haiti

Besides being used for recreational purposes such as skydiving, parachutes play an important role in the humanitarian efforts of many governments. One of the first uses of parachutes to aid humanitarian efforts was the Berlin Airlift of 1948–1949 (*www.history.com/this-day-in-history/berlin-airlift-begins*). As tensions rose at the onset of the Cold War, the Soviet Union prevented any people or goods from entering West Berlin in Germany. In response, the United States and United Kingdom organized efforts to airdrop food, supplies, and coal (for power) into West Berlin. By the end of the Soviet blockade in 1949, over 200,000 flights had been made into and over Berlin.

The airdrop remains one of the more effective tools for bringing food and necessary supplies, such as medicine, to people that need it. Figure L9.1, for example, is a picture of the airdrop that took place in Haiti after the 2010 earthquake that nearly destroyed the city of Port-au-Prince.

Air resistance affects the net force acting on a falling object, although in some conditions the effect is negligible and/or not observable. Newton's second law states that the acceleration produced by a net force on an object is directly proportional to the magnitude of the net force, is in the same direction as the net force, and is inversely proportional to the mass of an object; or, in mathematical terms, acceleration equals net force divided by mass.

The acceleration of a falling object without air resistance is $-9.8\ m/s^2$ because the net force acting on the falling object is equal to the force of gravity. However, when air resistance is present, then the net force on the object changes, because the force of air resistance counters the force of gravity.

An engineer needs to consider several different issues and work through a multistep design process in order to create a new parachute. The first step in the design process is to determine the performance specifications of the new parachute. This step requires the engineer to think about the minimum and maximum mass of any object that will be attached to the parachute and the maximum terminal velocity that the object will reach as it falls to the ground. Terminal velocity is the highest velocity attainable by an object as it falls through the air. Terminal velocity occurs when the drag force acting on the falling object is equal to the force of gravity. At this point, the sum of the forces acting on the object equals zero, and the resulting acceleration will be zero. A safe landing velocity for an object is usually between 2 and 5 m/s. The second step in the design process is to build a parachute with a specific surface area that will meet these important performance specifications. It is therefore important for engineers to understand how the surface area of a parachute affects the force of air resistance that acts on an object as it falls to the ground.

Your Task

Use what you know about forces and motion, structure and function, and models to design and carry out an investigation to determine how parachute surface area affects the force due to air resistance.

The guiding question of this investigation is, ***How does the surface area of a parachute affect the force due to air resistance as an object falls toward the ground?***

Materials

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

Consumables
- Large trash bags
- Tape
- String or fishing line

Equipment
- Safety glasses or goggles (required)
- Electronic or triple beam balance
- Washers
- Stopwatch
- Ruler
- Meterstick

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.

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Safety Precautions

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

1. Wear sanitized safety goggles or glasses during lab setup, hands-on activity, and takedown.
2. Do not throw the washers or the parachutes.
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 carry out an experiment. 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 are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- How might the structure of a parachute relate to its function?
- How will you determine the surface area of a parachute?
- How will you measure the force of air resistance?
- What will be the independent variable and the dependent variable for your experiment?

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

- What conditions need to be satisfied to establish a cause-and-effect relationship?
- What measurement scale or scales should you use to collect data?
- What equipment will you need to make the measurements?
- What other variables will you need to control during your experiment?
- Do you need to include a control group?
- 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 and organize the data you collect?

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

- What type of calculations will you need to make?
- What types of models can you use to help you analyze the motion of a parachute?
- How could you use mathematics to describe a relationship between variables?
- What types of patterns might you look for as you analyze your data?
- Are there any proportional relationships that you can identify?
- What type of table or graph 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

- how the culture of science, societal needs, and current events influence the work of scientists; and
- the role of imagination and creativity 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 L9.2.

FIGURE L9.2
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!