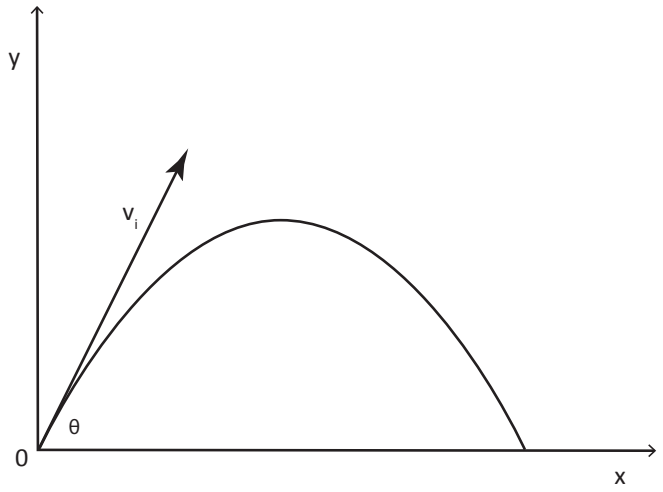
Lab Handout

Lab 3. Projectile Motion: How Do Changes to the Launch Angle, the Initial Velocity, and the Mass of a Projectile Affect Its Hang Time?

Introduction

Projectile motion is defined as the flight of an object near the Earth's surface under the action of gravity alone. Understanding the factors that affect the motion of projectiles has led to several major milestones in human history. Take spears as an example. Anthropologists have found evidence that human ancestors used stone-tipped spears for hunting 500,000 years ago (Wilkins et al. 2012). The ability to make and then use a spear to hunt large animals allowed our ancestors to gather more food. Later on, as people developed a better understanding of the factors that govern projectile motion, they were able to build new tools for launching projectiles that could travel farther in the air and hit targets with great accuracy. These tools included such things as bows and arrows, trebuchets, and cannons.

FIGURE L3.1
Projectile parabola



When a projectile is in flight, we assume that gravity is the sole force acting on it. The path of a projectile is a curve called a parabola, as shown in Figure L3.1. The projectile will have both a horizontal and vertical component to its velocity at any given time. Although scientists recognize that air resistance does affect the flight of a projectile, under most circumstances the effect of air resistance can be ignored. When we ignore air resistance, the initial velocity of the projectile governs the horizontal component of the projectile's velocity and the force of gravity governs its vertical component.

People often want to be able to predict how long a projectile will stay in the air (i.e., the hang time) after it is launched. There are a number of variables that may, or may not, affect the hang time of a projectile. These variables include the launch angle (denoted as θ) the initial velocity of the projectile, and the mass of the projectile. Some of these variables may also interact with each other, so the effect of any one variable may differ depending on the value of another variable. People therefore need to understand not only how these three variables affect the motion of a projectile but also how they interact with each other to predict how long a projectile will remain in the air after it is launched.

LAB 3

Your Task

Use what you to know about both linear and projectile motion, the importance of looking for patterns in data, and how to identify causal relationships to design and carry out a series of experiments to determine which variables impact the hang time of a projectile.

The guiding question of this investigation is, ***How do changes to the launch angle, the initial velocity, and the mass of a projectile affect its hang time?***

Materials

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

Consumable
- Tape

Equipment
- Safety glasses or goggles (required)
- Marble launcher
- Marbles (different sizes and masses)
- Protractor
- Tape measure
- Stopwatch

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 marbles or launch them at people.
3. Do not stand on tables or chairs.
4. Pick up marbles and other materials on the floor immediately to avoid a trip, slip, or fall hazard.
5. 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 several different experiments. Each experiment should look at one potential variable that may or may not affect the hang time of a projectile. 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 the components of the system you are studying?
- Which variable or variables could cause a change in the hang time of a projectile?
- What information will you need to track changes in these variables?
- What information will you need to be able to track changes in the hang time of a projectile?
- What will be the independent variable and the dependent variable for each 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 will you hold constant during each experiment?
- What variables will need to be controlled during each experiment, and how will you control them?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?

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

- What types of patterns might you look for as you analyze your data?
- How could you use mathematics to describe a relationship between variables?
- What type of calculations will you need to make?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

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

- the difference between observations and inferences in science, and
- the nature and role of experiments in science.

Initial Argument

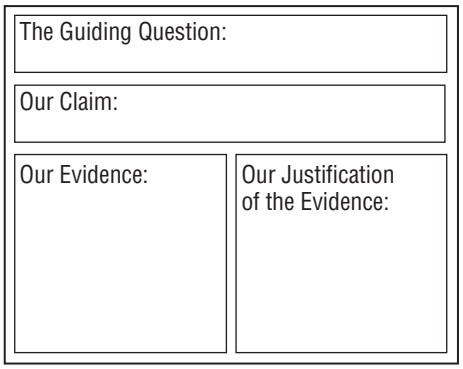
Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* 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 L3.2 (p. 84).

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.

FIGURE L3.2

Argument presentation on a whiteboard



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!

Reference

Wilkins, J., B. J. Schoville, K. S. Brown, and M. Chazan. 2012. Evidence for early hafted hunting technology. *Science* 338 (6109): 942–946.

Checkout Questions

Lab 3. Projectile Motion: How Do Changes to the Launch Angle, the Initial Velocity, and the Mass of a Projectile Affect Its Hang Time?

1. Given the models you created during your investigation of $t(\mathbf{v}_0)$ and $t(\theta)$, choose two instances for $\mathbf{v}_0$ and θ for which the hang time of the projectile is 2 seconds.

2. Let the acceleration due to gravity be expressed as $\mathbf{a} = -\mathbf{g}$ and the initial velocity of the projectile in the **y** direction as $\mathbf{v}_0 = \mathbf{v}\sin\theta$. Given the equation for the change in **y** below,

$$\Delta\mathbf{y} = \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$$

   write an equation for hang time, t, as a function of $\mathbf{v}_0$, θ, and **g**.

3. Current scientific knowledge and the perspectives of individual scientists influence inferences but not observations.

   a. I agree with this statement.
   b. I disagree with this statement.

   Explain your answer, using an example from your investigation of projectile motion.

4. Scientists use experiments to prove ideas.

   a. I agree with this statement.
   b. I disagree with this statement.

   Explain your answer, using an example from your investigation of projectile motion.

5. Why is it useful to identify patterns during an investigation? In your answer, be sure to include examples from at least two different investigations.

6. Why is identifying cause-and-effect relationships so important in science? In your answer, be sure to include examples from at least two different investigations.