LAB 2. PROJECTILE RANGE

Investigation

A spring-powered launcher clamped on a lab table fires a one-inch steel ball, which lands on the floor. You will experimentally find how changing the launch angle affects the distance traveled by the ball before it strikes the ground. In particular, you want to find the launch angle that allows the ball to travel the farthest before landing.

You also will make a mathematical model of the projectile's trajectory and use that model to predict the angle of greatest range. You will compare the model's predictions to your data.

Approach

You and your group will decide what measurements to take and what analyses to perform to answer the investigation question. Before you begin, decide what measurements you will need and how to take them. Communicate your plan to the instructor before taking any measurements. Your experimental **plan must be approved before you begin** for your lab to receive credit. Before you leave the lab, show your data to the instructor to verify that it is complete, sufficient, and realistic. Your **data must be approved before you leave** for your lab to receive credit.

These instructions will get you started with a procedure to find the speed at which the steel ball leaves the muzzle of the launcher. Finding the range at different launch angles is up to you.

Questions to ponder

What are the equations of motion for the trajectory of a launched projectile?

What launch angle gives the greatest range for a projectile launched from a lab table onto the floor?

Tasks

- Find the muzzle speed.
- Find how consistent the muzzle speed is.
- Measure the launch height.
- Measure the range resulting from a variety of launch angles.
- Find the launch angle giving greatest range.
- Record your primary data in a manner clear enough for a reader to understand what you did and what you found.
- Mathematically model the projectile's range given launch height, speed, and angle.
- Use the mathematical model to predict the greatest range and the angle producing it.
- Compare the data to the model.

Operating the Launcher

Description

The launcher propels its projectile using a compressed spring. The spring can be set at three different starting compressions. The barrel pivots up and down to adjust the firing angle. A protractor with a small built-in plumb line measures the launch angle. The muzzle is the end of the barrel near the pivot, so that changing the launch angle does not change the launch height.

In this activity you will clamp the launcher to a table and fire a projectile onto the floor from different initial angles. You will then compare the observed trajectories to predictions from a simple ballistic model.

Supplies

Projectile launcher, projectile, ramrod, clamp, plumb line, measuring tape, meter stick, carbon paper, white paper, tape, sturdy table, safety goggles or glasses

Safety considerations

- The projectile launcher fires a 1″ steel or hard plastic ball at speeds that can be considerable. To avoid eye injury, **everyone in the room must wear safety glasses or goggles while launchers are in use.**
- **Never look down the muzzle** of barrel. You can see into the barrel through the slots cut in the sides.
- Once the barrel is loaded, be careful not to place any part of your (or anyone's!) body in front of the launcher.
- Use the ramrod for loading and cocking the launcher. **Never** poke your fingers into the launcher—you could very easily break them! That would be bad.
- Load the projectile launcher with 1″ balls only. Other loads may cause dangerous conditions.

Setup

Place the launcher at the edge of the table, with the muzzle of the barrel pointing away from the table. Clamp the launcher firmly to the table. Use two clamps, one on either side of the base, if available. If only one clamp is available, put it on the side under the barrel of the launcher. Clear the line of fire so that the trajectory is not obstructed.

Firing

Place the projectile into the muzzle of the launcher. Push it into the barrel using the ramrod. As you push it in, the trigger on the top of the barrel will rise and fall with a click up to three times. After each click, the launcher is cocked in that position.

If the barrel is horizontal, check that the projectile is against the cradle by looking through the slots in the side of the barrel. If the projectile has rolled forward, gently push it back against the cradle with the ramrod.

Check the launch angle displayed by the protractor and plumb line.

Check that no one is in the line of fire.

Fire the launcher by pulling up on the trigger.

Watch the projectile as it travels and bounces so that you can retrieve it.

Place the catcher box so that the projectile lands into it on successive launches.

Care of the launcher

Do not fire the launcher without a load. Such a “dry fire” may damage the launcher. If you wish to release a cocked spring without firing, insert the ramrod into the barrel against the cradle and, while holding the ramrod firmly in place, release the trigger. Slowly ease the ramrod out of the barrel.

Do not over tighten the plastic wing nuts. They can easily strip and split.

Measurements

Activity1. Finding launch speed

In this activity, you will fire five shots horizontally off the table onto the floor and measure the distance traveled. Assuming the projectiles accelerate downward with magnitude g, you will calculate how long they were in the air, and thus how fast they were moving horizontally.

1. Adjust the barrel to fire horizontally.
2. Measure the height of the muzzle above the floor. *Record the height in your data sheet.*
3. Using the plumb line, find the point on the floor directly beneath the muzzle. Mark this point with tape.
4. Load, cock, and fire the launcher. Note where the projectile lands.
5. Tape a piece of white paper onto the floor where you saw the projectile land. Place a piece of carbon paper, carbon side down, atop it. Place another piece of white paper atop the carbon paper to protect it from tearing.
6. Check that the launch angle is still horizontal. Adjust if not.
7. Load, cock, and fire the launcher.
8. The projectile should have landed on the paper and made a mark on the white paper on the floor. Leaving this paper taped to the floor, find the mark and label it.
9. Replace the carbon paper and protective sheet.
10. Repeat steps 6–9 for a total of five shots onto the paper.
11. Measure the distances from the point on the floor beneath the muzzle to the shots on the paper. *Record these distances.*

Activity 2. Range

What different launch angles should you use to create a complete picture of range vs. launch angle? How many different angles should you use, and how many shots at each angle? How can you best pinpoint the launch angle that gives the greatest range? Make your plan, present it to your instructor for approval, and carry it out once it is approved.

Calculate the average range for each launch angle. How much do individual measurements deviate from the average?

Lab Report

The lab report for this lab will be a little less involved than a full lab report, so this lab is worth 85 points.

Abstract (0 points)

"A commercial projectile launcher was used to fire a steel ball at different launch angles from a lab table onto the floor. The launch speed was estimated from the range of horizontal shots, and the launch angle giving the greatest range was found experimentally. The result was checked against a theoretical model."

Purpose (5 points)

Choose the best of the options below.

To find the launch angle giving the greatest range of a ballistic projectile.

To test a mathematical model of projectile motion.

To get practice working with equations of projectile motion

Theory (10 points)

This lab includes trajectories, mathematical models, max-min problems, and experimental variability, so there is no shortage of things to consider. For this lab, do the following.

- Identify the equations of motion applying to the projectile.
- Identify the formula the equations yield for the range of the projectile.
- Explain how to find the theoretical launch angle giving the greatest range from the formula.

Experimental (15 points)

Describe the apparatus you used and the procedure you followed to find the effect of launch angle on range. Identify steps you took to minimize experimental and measurement error.

Observations and Data (15 points)

Your primary data should be recorded in your data tables. In your report, present the data as a graph of range vs. launch angle. Report quantities not on the graph (e.g., initial height).

Analysis and Discussion (30 points)

Identify known or suspected errors in your measurements. Explain how these errors would affect your measured and calculated values.

Identify known or suspected sources of variability in your trials. (Why might shots from the same spring compression and the same launch angle land at different distances?)

Discuss your level of confidence in your estimate of $v_{0,}$ the projectile's muzzle speed.

Identify and explain your best estimate of the optimal launch angle and its resulting range.

Discuss how well the theoretical predictions match your observations for all launch angles. Suggest reasons for mis-matches.

Conclusion (10 points)

Discuss how and why the optimal angle matches, or does not match, the theoretical optimal angle for a projectile landing at the same height as its launch.